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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

# GEOLOGY AND MINERAL RESOURCES OF MISSISSIPPI

BY

A. F. CRIDER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

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# GEOLOGY AND MINERAL RESOURCES OF MISSISSIPPI.

By A. F. Crider.

## INTRODUCTION.

By Edwin C. Eckel.

The following sketch of the geology and mineral resources of the State of Mississippi has been prepared to serve as a summary of present knowledge of those subjects. Much detailed field work in the State will be required before any complete discussion of its geology can be presented, but it is hoped that the outline given here will be of service, particularly in indicating the lines along which the development of Mississippi's mineral resources will probably take place.

It is with pleasure that this opportunity is taken of acknowledging indebtedness to previous workers in the same field. In the preparation of the present sketch free use has been made of the various reports and papers published by Dr. Eugene Hilgard, former State geologist. Dr. Eugene A. Smith, formerly assistant to Doctor Hilgard and now State geologist of Alabama, has very generously furnished notes on various phases of Mississippi geology. Mr. L. C. Johnson, of Pachuta, Miss., who has spent many years in geologic work in the State, has also contributed numerous data.

In a paper recently published in the Transactions of the Mississippi Historical Society, Doctor Hilgard has given an outline of the principal events in the history of the Geological and Agricultural Survey of the State of Mississippi, from its formation in 1850 to its untimely cutting off in 1872. A summary of this valuable outline is as follows:

The Geological and Agricultural Survey of the State of Mississippi had its origin in an act of the legislature entitled "An act to further endow the University of Mississippi," which was approved by the governor March 5, 1850, and took effect June 1 following. This act provided that $3,000 should be semiannually appropriated for the support of the agricultural and geologic departments of the university, at least one-half of which sum was to be expended in making a general geologic and agricultural survey of the State. Annual reports were to be made to the governor by the trustees of the university. This act, together with later legislation in 1852, 1854, and 1860, was the basis of all geologic work carried on by the State.

In 1852, Prof. B. L. C. Wailes took up active work under the act of 1850, and in 1854 an appropriation for the publication of his report was made by the legislature. Professor Wailes was succeeded as State geologist in 1854 by Prof. Lewis Harper, and in 1857 another report was published. Both of these reports, particularly that of Professor Wailes, contain matter of much geologic and agricultural interest; but they are far inferior to the third report, published in 1860 by Dr. Eugene Hilgard, then State geologist. This is still the best available book on the geology of the State of Mississippi.

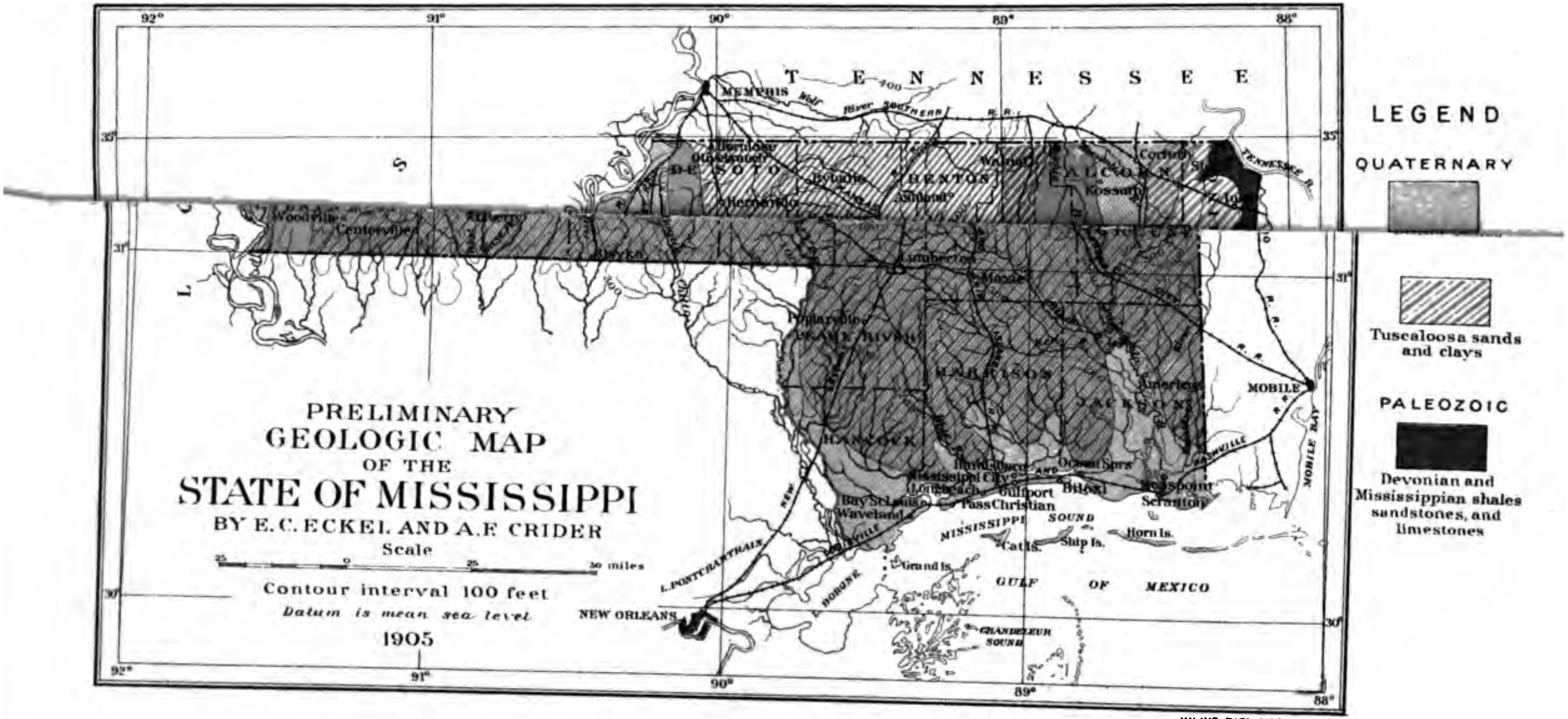
Doctor Hilgard's report, though printed in 1860, was not generally distributed until 1866, as the entire edition was sent to St. Louis for binding in November, 1860, and remained there until the close of the war. Doctor Hilgard's work on the geology and agriculture of the State had, however, deeply impressed its citizens. The following quotation from his history of the survey is of interest in this connection:

> As a striking exemplification of the change wrought in public sentiment by the energetic prosecution of agricultural survey work, I may quote the action taken at the called session of the legislature of Mississippi in August, 1861. Under the terrible stress brought to bear on the State even then by the impending conflict, it would have been natural to expect the complete extinction of the appropriation for the survey work. Instead of this, an act was passed suspending the appropriation for the geological survey "until the close of the war, and for twelve months thereafter; except the sum of $1,250 per annum, which shall be applied to the payment of the salary of the State geologist and the purchase of such chemicals as may be necessary to carry on the analysis of soils, minerals, and mineral waters, and to enable him to preserve the apparatus, analyses, and other property of the State connected with said survey." This appropriation was actually maintained during the entire struggle of the Confederacy; and so far as the vicissitudes of war permitted, the chemical work (and even some field work) was continued by me during the same time. The scarcity of salt suggested a utilization of some of the saline waters and efflorescences so common in the southern part of the State, and some forty (unpublished) analyses of such saline mixtures are on record. I made an official report on the subject to Governor Pettus, dated June 9, 1862. I also made a special exploration on the several limestone caves of the State, with a view to the discovery of nitrous earths; but from the fact that these caves are all traversed by lively streams, I found nowhere a sufficient accumulation of nitrates to render exploration useful.
>
> Soon after the beginning of active hostilities in Tennessee, the university faculty having been dissolved, I was detailed by the governor, as commander of the State militia, to take charge of the State property at the university during the war; and this, as well as a subsequent appointment by the Confederate authorities as an agent of the "niter bureau," prevented my being called into active service, except on the occasion of the siege of Vicksburg, when, toward the end of that memorable epoch, I was ordered to erect "calcium lights" on the bluffs above the city, for the illumination of the Federal gunboats when attempting to run the gauntlet of the batteries. The difficulties of construction and procuring of the necessary materials delayed the completion of the arrangements, so that on the occasion of the final passage of the fleet no adequate light could be given. From a hospital at Jackson, where I was a patient at the time of its first capture, I soon afterwards made my way to my post at Oxford, where I remained on duty during the rest of the war. This duty was oftentimes a very arduous one, Oxford being then within the "belt of desolation" between the two armies, which swept back and forth over it. The survey collections had several very narrow escapes from destruction when the buildings were hastily occupied for hospital purposes; they were several times transferred on hospital cots from one building to another, but finally escaped without any material injury. Not so the collections at the capitol at Jackson, where the shelves and cases seem to have been swept with the butts of muskets, and the floor was strewn with broken specimens and shattered glass jars. About one-third of the collections stored there was entirely ruined, and of the remainder nearly all the labels were lost.

In 1866, as the period for which the survey appropriation was suspended had elapsed, work was again taken up by Doctor Hilgard. Several assistants aided him in this at different times, prominent among these younger men being Dr. Eugene A. Smith, now State geologist of Alabama. No further report was published by the State, however, and in 1872, during the days of reconstruction, the State auditor decided that the survey appropriation should not be paid. This arbitrary action, which could not be prevented under the circumstances then existing, put a final stop to the Geological and Agricultural Survey of the State.

Under the energetic and capable administration of Doctor Hilgard it had accomplished much of direct practical benefit to the citizens of the State, while its purely scientific results were many and important.

In recent years considerable work has been carried on in Mississippi by the United States Geological Survey, resulting in several reports on various phases of Mississippi geology and mineral resources. In 1903 a limited cooperation was effected between the State and this Federal organization, Mr. R. H. Henry, World's Fair commissioner for Mississippi, having requested the aid of the United States Geological Survey in securing an adequate representation of Mississippi's mineral resources at the St. Louis exposition. The field work arranged for under this cooperative agreement was carried out in 1903 and 1904 by Mr. A. F. Crider, under the supervision of Mr. E. C. Eckel. The amount of time and money available for this field work was insufficient to provide for a detailed survey of the entire State. Attention was concentrated, therefore, on certain geologic formations which were directly of interest to Mississippians because of the mineral industries which might be based on them.



PRELIMINARY
GEOLOGIC MAP
OF THE
STATE OF MISSISSIPPI
BY E. C. ECKEL AND A. F. CRIDER

Contour interval 100 feet
*Datum is mean sea level*
1905

JULIUS BIEN & CO. LITH. N.Y.

## GEOLOGY.

Though the general geologic structure of Mississippi is very simple, the details of the stratigraphy are hard to make out, owing largely to the extent to which the underlying rocks are covered by the more recent deposits, such as the alluvial deposits and the "Orange sand," or Lafayette formation.

The oldest rocks in the State are a series of limestones and shales of Devonian and Carboniferous age, which outcrop in northeastern Mississippi, covering much of Tishomingo County and a small portion of Itawamba County.

The newer rocks outcrop south and west of this older mass, occupying successive roughly parallel bands, and all of these rocks dip slightly to the southwest, so that if the observer should start in Tishomingo County and travel through the State either to the south or west he would find himself continually passing over newer and newer series of rocks, until he finally reached the very recent alluvial deposits which fringe the Gulf and Mississippi River. The above conditions are shown in the cross sections (figs. 1 to 5).

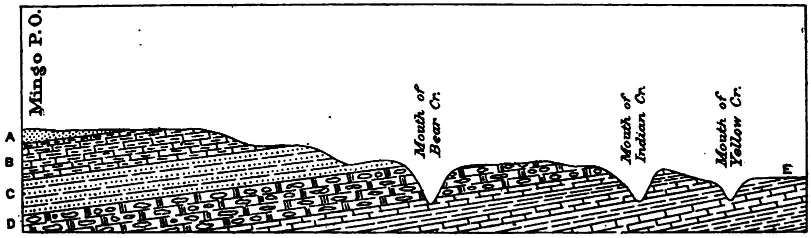


FIG. 1.—Cross section from mouth of Yellow Creek to Mingo. A, Cretaceous; B, Chester; C, St. Louis; D, Tullahoma; E, Devonian.

The following table shows the geologic groups which are exposed in Mississippi, the newest formations being at the top of the table and the oldest at the bottom:

*Geologic formations of Mississippi.*

| | | | |
|---|---|---|---|
| Quaternary | | | River alluvium—Sands, silts, and loam. |
| | | Loess | Yellow loam—Surface loam or brick clays of northwestern Mississippi. |
| | | | Loess—Gray to buff-colored calcareous silt containing land shells. |
| | | | Port Hudson—Greenish to bluish clays with interbedded sands; calcareous concretions in lowest members. |
| | | | Lafayette—Red to yellow sands and iron-stained pebbles; sands in places containing large amount of clay. |
| Tertiary | Miocene(?) | | Grand Gulf—Gray aluminous sandstones, interbedded with white to gray plastic clays in northwest; darker colored clays containing lignitized wood and vegetable matter southeast. |
| | Miocene | | Pascagoula—Calcareous clays containing numerous fossils. |
| | Oligocene | | Vicksburg—White, yellow, and blue crystalline limestone, interbedded with thin layers of indurated marl and clay. |
| | Eocene | | Jackson—Gray calcareous clays, lignitic clays with gray siliceous sands and some green sand. |
| | | Claiborne | Lisbon—Calcareous clays and greensands. |
| | | | Tallahatta buhrstone—Aluminous and quartzitic sandstones, greensands, and clay stones. |
| | | | Wilcox—Highly stratified sands and clays of various colors, with some greensand-marl beds. |
| | | Midway | Porters Creek—Gray aluminous clays. |
| | | | Clayton—Limestone, sands, and clays. |
| Cretaceous | | | Ripley—Limestones, sandstones, and marls. |
| | | | Selma Chalk—White chalky limestone and blue calcareous clays. |
| | | | Eutaw—Siliceous sands and clays, with some greensand. |
| | | | Tuscaloosa—Variegated sands and clays. |
| Carboniferous | | | Chester—Sandstone, limestone, and clays. |
| | | | St. Louis—Limestone and chert. |
| | | | Tullahoma—Siliceous chert. |
| Devonian | | | New Scotland—Dark limestone and shale. |

## DEVONIAN.

Until recently the oldest rocks of Mississippi have been referred to the Lower Carboniferous, but a more thorough investigation has proved the presence of a fauna referred, by Charles Schuchert, now of Yale University, and E. M. Kindle, of the United States Geological Survey, to the New Scotland beds (lower Devonian) of New York. These newly recognized beds outcrop along the west bank of Tennessee River and some of its smaller tributaries in northeastern Tishomingo County. The New Scotland fossils were first found along Yellow Creek, in secs. 15 and 22, T. 1 N., R. 10 E.

Yellow Creek rises southwest of Candler post-office, on the west side of Tishomingo County, flows in a general northerly direction, and empties into Tennessee River just north of the State line between Mississippi and Tennessee. Along its headwaters and middle course the stream flows over lower Cretaceous strata which overlap the older sea floor.

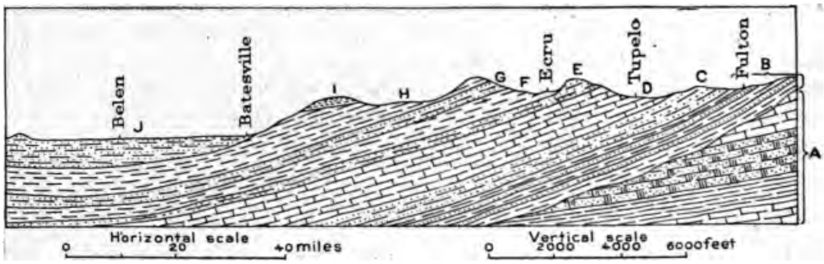


FIG. 2.—Cross section from Alabama to Mississippi River, in latitude of Tupelo. J, Port Hudson; I, loess; H, Wilcox; G, Porters Creek; F, Clayton; E, Ripley; D, Selma; C, Eutaw; B, Tuscaloosa; A, Paleozoic.

At Doskie post-office, on the west side of R. 10 E., Yellow Creek first begins to cut into the older strata, and from this place to Tennessee River the older rocks occur at intervals in the bed of the creek. Along its lower course, in secs. 27, 22, 15, and 14, the creek has channeled its bed into the hard limestone rocks, leaving perpendicular cliffs, in places more than 100 feet high. Above these cliffs are hills rising 150 feet higher and covered with Cretaceous and Lafayette deposits.

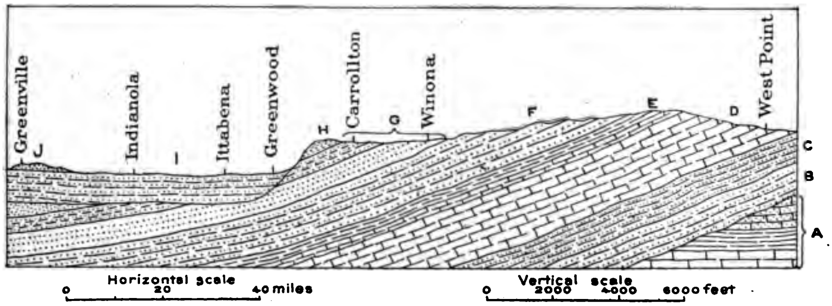


FIG. 3.—Cross section from West Point to Greenville. J, river alluvium; I, Port Hudson; H, loess; G. Tallahatta; F, Wilcox; E, Midway; D, Selma; C, Eutaw; B, Tuscaloosa; A, Paleozoic.

The deep gorges of this region form a striking feature of the topography. The steepness of the slopes and the narrowness of the valleys indicate a rapid uplift which has caused the streams to erode the bottoms of their channels faster than the sides.

Below is given a section of the strata along Yellow Creek in sec. 22, T. 1 N., R. 10 E. At this place the creek is at present hugging the east bank—a cliff 140 feet high. There is a narrow bottom on the west side of the creek, the cliff on this side receding more gently than on the east.

*Section along Yellow Creek, in sec. 22, T. 1 N., R. 10 E.*

| | Feet. |
|---|---|
| 4. Thin-bedded, impure limestone at base, changing gradually to a bluish limestone at top of cliff | 95 |
| 3. Compact blue limestone, nonfossiliferous | 40 |
| 2. Dark-gray limestone containing *Tentaculites gyracanthus, Dalmanites* cf. *micrurus, Chonostrophia* sp.? *Spirifer cyclopteris, Stropheodonta planulata, Leptæna rhomboidalis, Platyceras tenuiliratum, Anoplotheca concava, Dalmanites pleuropter, Rhipidomella oblata, Meristella arcuata, Avicula* cf. *subequilatera, Stropheodonta beckei, Chonostrophia helderbergia* | 10 |
| 1. Dark-colored, pure limestone containing *Callopora* cf. *perelegans* to water's edge | 5 |

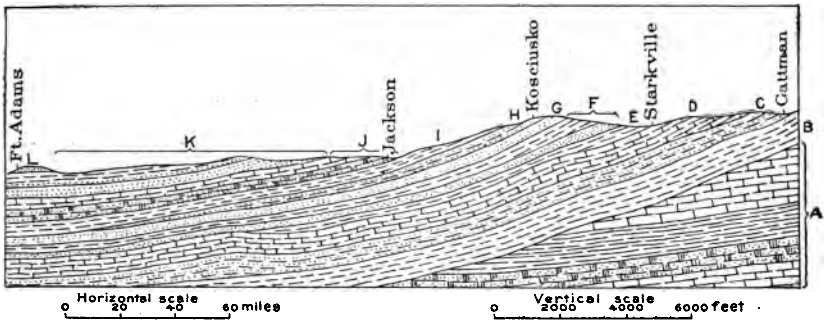


FIG. 4.—Section from Gattman to Fort Adams. L, loess; K, Grand Gulf (sandstone and clay); J, Vicksburg (limestone); I, Jackson (clays and marls); H, Claiborne; G, Tallahatta (sandstone); F, Wilcox (sands and clays); E, Midway (limestone and clays); D, Selma (limestone); C, Eutaw (sands and clays); B, Tuscaloosa (sands and clays); A, Paleozoic (limestone, etc.).

At the point where the public road crosses the creek in sec. 15, T. 1 N., R. 10 E., the dark-blue limestone occurs at the water's edge and extends to a height of about 50 feet. On the north side of the creek the contact between the dark-blue limestone and the thinner bedded shaly limestone passing into blue shale is studded with the following fossils, which occur in a thin ledge of silicified chert: *Orthothetes woolworthanus, Rhipidomella subcarinata, Proetus protuberans*, and many of the forms found in the above list. Owing to the detritus which has covered the hillside it was impossible to determine the thickness of this fossiliferous horizon, but it is measured in inches rather than in feet. The same dark-blue limestone is reported to form the cliffs on both sides of the stream from this point to the mouth.

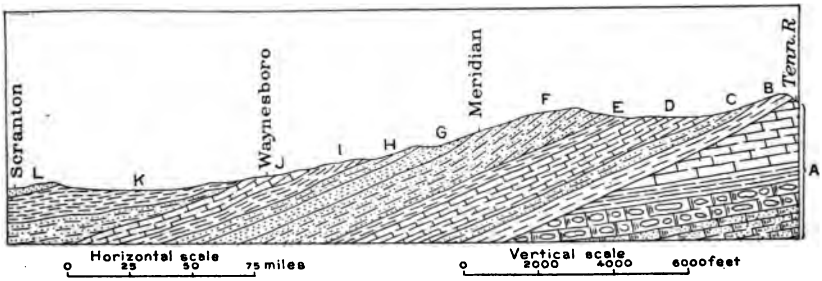


FIG. 5.—North-south cross section from Scranton to Tennessee River. L. Quaternary (silts); K, Grand Gulf; J, Vicksburg; I, Jackson; H, Claiborne; G, Tallahatta; F, Wilcox; E, Sucarnochee; D, Selma; C, Eutaw; B, Tuscaloosa; A, Paleozoic.

In the northwest quarter of T. 2 N., R. 10 E., where the Iuka and Red Bluff Springs road crosses Yellow Creek, the limestone outcrops for one-half mile above the ford. At the "big rock" the limestone is horizontally bedded and when long exposed breaks down into thin shelly layers. It is a very compact, fine-grained, dark-blue rock, and, when freshly broken, gives a strong fetid odor. At about 30 feet above the creek at this point is a highly silicified bed of angular chert, or hornstone, destitute of fossils.

Three-fourths of a mile north of the bridge at the old McMaster mill the dark-blue limestone is well exposed in the creek and road. At this place the overlying soil has been removed, leaving half an acre or more of the rock exposed. There are in the limestone two well-marked sets of joints. The main set extends N. 25° E. and a secondary set is practically at a right angle to the first. Overlying the dark-blue limestone are about 25 to 30 feet of angular flint and hornstone.

Along Whetstone Creek, which empties into Tennessee River east of Short post-office, the following section is shown:

*Section on A. L. Bugg's land at mouth of Whetstone Creek, near Short.*

| | Feet. |
|---|---|
| 4. Angular chert, flint, and hornstone, devoid of fossils | 100 |
| 3. Dark-colored shale containing iron pyrite; very fossiliferous in lower part | 30 |
| 2. Dark-blue nonfossiliferous limestone, with well-marked joints trending N. 20° E | 20 |
| 1. Thin-bedded, fine-grained, shaly limestone, with thin bands of fine-grained sandstone or whetstone varying from a fraction of an inch to 12 inches in thickness | 20 |

No. 3 of this section perhaps represents the top of the Devonian. Unfortunately the fossils coming from this stratum were lost, so that the exact horizon can not at present be determined. The siliceous chert here and at McMaster's mill represents the lowest member of the Carboniferous and rests on the Devonian shale.

Farther south, near the mouth of Bear Creek, the siliceous chert bed continues to thicken, reaching a maximum thickness of 150 feet. Here the chert, as at Whetstone Creek, caps the tops of the hills. Still farther south along Bear Creek the St. Louis and Chester formations occur at a higher altitude. Fig. 1 (p. 7) shows the relations of the New Scotland beds to the later formations. There is a very perceptible dip of the older rocks to the south.

A well section at the mouth of Bear Creek shows 160 feet of shaly, dark-colored limestone, 140 feet of dark-gray shale, and 450 feet of gray limestone. The gray limestone is no doubt the equivalent of the gray limestone at the mouth of Yellow Creek, where the New Scotland fauna was collected. The well was begun in the limestone at the foot of the hill, the top of which is covered with siliceous chert.

## MISSISSIPPIAN (LOWER CARBONIFEROUS).

Overlying the Devonian rocks is the Mississippian (Lower Carboniferous) series of cherts, limestones, sandstones, and shales. The thickness of these beds in Mississippi is not known, but is perhaps 800 or 900 feet. The beds are comparatively little disturbed, with a southward dip of about 40 feet per mile and a westward dip of about 20 feet per mile. The Carboniferous rocks represent the southwestern extremity of the southern Appalachian plateau, whose southern and western slopes are overlapped by the later formations.

### TULLAHOMA FORMATION.

The lowest formation of the Mississippian series consists of 130 to 150 feet of angular fragments of chert or flint which is correlated with the Tullahoma or Lauderdale chert of the Alabama survey.[a] It is thickest near the mouth of Bear Creek and thins to the north.

The group in Alabama is described by McCalley as a siliceous chert, interbedded with argillaceous and calcareous shales, containing beds of limonite ore. The principal materials in Mississippi are highly siliceous fragmental chert, pulverized silica, and residual clay. In its unweathered condition the chert is stratified, but near the surface it occurs in angular fragments varying in size from sand grains to bowlders weighing tons. In places the chert has weathered into beds of snow-white or yellow pulverulent silica. Near the mouth of Bear Creek are large bodies of it which were mined for several years for an abrasive. Near the surface the silica often forms a white to yellowish clay or kaolin. A fine grade of china ware has been made from a deposit of this clay on Whetstone Creek.

---

[a] Rept. Geol. Survey of Alabama, pt. 1, Tennessee Valley Region, p. 35.

The Tullahoma chert is thinnest in the north. At the old McMaster mill it is represented by a thickness of 30 feet. Near the mouth of Whetstone Creek the formation has thickened to 100 feet, and at the mouth of Bear Creek, on the Alabama border, it has a thickness of 150 feet.

Along the headwaters of the small streams flowing into these larger streams the chert is always present and extends westward until it is covered by the later Cretaceous deposits. The southward extension is limited by the St. Louis limestone, which overlies the chert.

### ST. LOUIS LIMESTONE.

Across the line in Alabama the St. Louis limestone has been recognized by McCalley[a] along Tennessee River, where it is about 150 feet thick. The characteristic fossil *Lithostrotion canadense* has never been found in Mississippi, though a more thorough search may show its presence.

This formation in Mississippi consists of a series of dark-blue to gray limestones with more or less chert through it. In places the limestone is quite fossiliferous. Many of the fossils were determined by Hilgard, but many of the names he used have now become antiquated. The St. Louis is distinguished from the Tullahoma by the fact that it has less chert and a greater amount of pure gray limestone.

In the upper part of the St. Louis there is a still lighter colored oolitic limestone containing *Platycrinus huntsvillei.* This no doubt is the equivalent of the Ste. Genevieve limestone of Missouri, southern Illinois, and western Kentucky. The area of the *Platycrinus* limestone in Mississippi is limited, being confined to secs. 22, 26, and 27, T. 4 N., R. 11 E. On John Trammel's land, in sec. 22, T. 4 N., R. 11 E., the limestone is overlain by the heavy-bedded sandstone belonging to the Chester formation. The Carboniferous west of this locality is covered with the Cretaceous and Lafayette formations.

### CHESTER FORMATION.

The upper division of the Carboniferous in Mississippi is represented by a series of sandstones, limestones, and shales belonging to the Chester group. The lowest member of the Chester is a compact, coarse-grained sandstone which rests on the oolitic St. Louis limestone. The thicknesses of the various beds are not known, owing to the scarcity of exposures, which occur along the larger streams where the overlying Cretaceous has been removed.

The changeable character of the lower part of the formation is clearly shown at the steel bridge across Bear Creek near Mingo, where the following section may be seen:

*Section at bridge across Bear Creek, near Mingo.*

| | Ft. | In. |
|---|---|---|
| 6. Top of hill covered with Lafayette. | | |
| 5. Heavy-bedded, coarse-grained sandstone | 20 | |
| 4. Fine-grained, dark-colored limestone giving rise to springs, with thin bands bearing *Spirifer increbescens*(?) | 4 | |
| 3. Highly fossiliferous shale | 22 | |
| 2. Coarse-grained limestone containing a large amount of iron oxide | | 6-8 |
| 1. Dark-colored compact shale | 10 | |

The sandstone continues along the creek to the south and becomes coarser in texture. This sandstone represents the uppermost member of the Chester formation in Mississippi. Along Bear Creek it attains a thickness of at least 100 feet and perhaps much more. This creek along its middle course has channeled its bed deep into the sandstone, leaving high perpendicular cliffs standing on either side.

The area of outcrop of the Chester formation is confined chiefly to the stream valleys along Bear Creek and its tributaries in eastern Tishomingo County, along the headwaters of Tombigbee River in southeastern Prentiss County, and along Bull Mountain Creek in eastern Itawamba County. The southernmost outcrop in the State occurs along Bull Mountain Creek near the northern edge of Monroe County. The area between these streams is covered with the much later Cretaceous deposits, which conceal the Chester except where vigorous erosion has removed them.

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[a] Op. cit., , p. 36.

The southernmost outcrop of the Chester limestone in Tishomingo County is at the old McDougle mill, on the headwaters of Mackys Creek.

No coal occurs in the Carboniferous rocks of Mississippi, as the Coal Measures do not outcrop within the limits of the State.

## CRETACEOUS.

### TUSCALOOSA FORMATION.

Between the uppermost member of the Carboniferous and the next overlying formation in northeastern Mississippi there is a marked unconformity. The overlapping formation, which is well shown near Tuscaloosa, Ala., has been called the Tuscaloosa.

In its lower part this formation is composed of dark-colored clays, thin seams of lignite, lignitic clays, and variegated sands and chert, and in the upper part of light-colored clays. The clays of the lower part are very compact, giving rise to numerous bold springs along the valleys where the clay has been cut into by the streams and is overlain by Lafayette sands and gravel. These clay horizons are often associated with beds of lignite and less pure clays which contain impressions of leaves and bits of lignitized wood. Where free from impurities the clay often forms a white to gray plastic material well adapted for making common jug ware. In places in Tishomingo and Itawamba counties the clay approaches a kaolin in appearance and purity and is used for making pottery.

Higher up in the formation the strata become more sandy in character, though there are more or less irregular beds of clay extending throughout the formation. The sands are irregularly bedded with a less amount of clay. It is impossible to trace any one horizon of sand or clay for any great distance. Along some of the larger streams, where good exposures are obtained, the material often changes within a hundred feet from a laminated clay to cross-bedded sands. There is more or less mica found throughout the formation in both the sands and clays.

The sands of the Tuscaloosa are, in places, of an Indian red color, and where they come into contact with the overlying Lafayette it often becomes impossible to separate the two formations. In other places the color changes from various shades of yellow to the many hues of red and purple. The sands are highly cross-bedded, as shown in Pl. II, *B*.

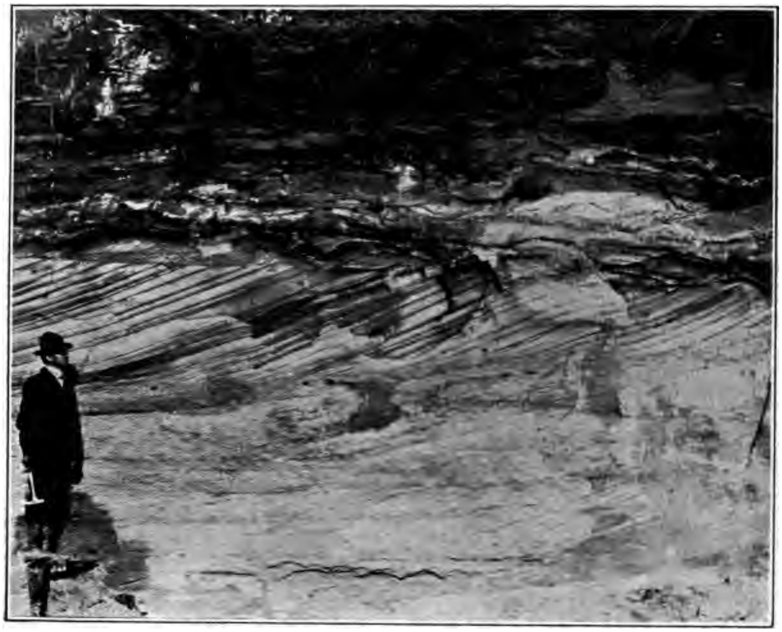
The thickness of the formation in western Alabama is estimated at 1,000 feet. It thins perceptibly to the north. At Corinth, Miss., the hard Paleozoic rocks of the old sea floor were found in the city waterworks well at a depth of 450 feet, and the upper sands of the Tuscaloosa at 180 feet, thus making the entire thickness of the formation in northern Mississippi but 270 feet. Still farther north, in Tennessee, the entire thickness of the Tuscaloosa and the next overlying formation, the Eutaw, taken together and described under the name of Coffee sands, is given by L. C. Glenn as 300 feet.

The area occupied by this formation is a long, irregular band 5 to 15 miles wide, extending north from the Alabama line due east of Columbus to the Tennessee boundary, including the northeastern portion of Lowndes, the eastern half of Monroe, and a narrow strip along the eastern portion of Prentiss and Alcorn counties, and overlapping the Paleozoic rocks in Tishomingo and northern Itawamba counties. Tombigbee River approximately marks the western boundary north of Monroe County, and southward to the Alabama line the western boundary lies within 3 to 8 miles east of the river.

In northern Tishomingo County the character of the lower part of the formation is shown in a well on Bascom Whitehurst's farm on the west side of Yellow Creek, in T. 1 N., R. 10 E. The section of this well showed 10 feet of surface red clayey sand and gravel belonging to the Lafayette; 10 feet of yellow sandy clay; 10 feet of white clay, very pure; 14 feet of black lignitic clay containing wood, "charcoal," and a large amount of pyrite nodules. The well stopped in white clay at a depth of 65 feet before reaching the hard Paleozoic rocks, which outcrop at the foot of the hill about 100 feet below the top of the well.

The same dark-colored clay interbedded with white clay occurs on the Iuka and Mingo road at Crippledeer Creek. On the north side of the creek the following section is shown:

*A*. OUTCROP OF VICKSBURG LIMESTONE AT ROCK CUT 1 MILE WEST OF CLINTON.



*B*. TUSCALOOSA SANDS NEAR IUKA.

*Section on north side of Crippledeer Creek.*

| | Feet. |
|---|---|
| 4. Lafayette sand of deep Indian-red color, containing a large amount of clay | 4 |
| 3. Yellowish-gray micaceous sandy clay, stratified | 4 |
| 2. Dark-colored shaly clay | 2 |
| 1. Clay containing small pebbles of quartz; has been used for making jug ware | 6 |

The hill on the south side of the creek shows 50 feet or more of dark lignitic clay which is at a higher elevation than the white clay on the north side. The Paleozoic rocks outcrop in the creek a short distance to the east and are no doubt present at the foot of the hill at this place, but are covered with the wash from the hills.

To the west of the eastern border of the Tuscaloosa, in Tishomingo County, the dark-colored clay which comes at the base of the formation gradually disappears and the lighter colored clay and sand become more prevalent. In places beds of pure white clay, comparatively free from sand, are reported to be 30 feet thick.

Farther south, in Itawamba County, somewhat different conditions prevail. In the northeastern part of the county, in the vicinity of Rara Avis, beds of gravel occur in the lower Tuscaloosa, along Bull Mountain Creek and its tributaries. A well at Amory, which is 249 feet above tide, obtained an artesian flow in sand and coarse gravel at a depth of 190 feet. This is overlain by 180 feet of pink clay and soapstone. An 8-foot bed of white gravel[a] overlying a stratum of black, fetid lignitic clay is reported to have been found at a depth of 217 to 220 feet in wells at Aberdeen at an altitude of 203 feet above sea level. The character of the gravel and the depth below the surface place these beds in the Tuscaloosa.

There is a difference in the gravel of the Lafayette and that of the Tuscaloosa. The latter is much less waterworn and occurs in angular fragments of various sizes from sand to large bowlders. On the whole there is but a small percentage of waterworn pebbles, and these have no regular shape, being usually angular fragments with the corners somewhat smoothed or rounded. These gravels bear Paleozoic fossils. The Lafayette gravel contains a larger proportion of quartz pebbles, which are oblong or egg-shaped and have evidently been transported over a greater distance.

The gravel beds of the Tuscaloosa no doubt occur farther north in Tishomingo County, but where these beds come into contact with the Tullahoma beds of angular residual chert it has not been possible in the limited time given to this region to make any distinction between them. It would seem plausible, however, that the angular chert beds found near the mouth of Bear Creek and containing rounded waterworn pebbles should be placed in the Tuscaloosa and not in the Tullahoma.

At various localities south and east of Fulton, Itawamba County, beds of pure lignite have been mistaken for bituminous coal. This is interbedded with sandy, lignitic, and highly micaceous clays. In places it overlies a white pottery clay of exceptional purity. Just above the bed of lignite is a thin ferruginous sandstone. The descending waters bearing iron oxide were checked by the impervious lignite and cemented the sand into a compact hard rock. There are many large springs in central Itawamba County, at this horizon. The lignite occurs on J. A. Hood's land, in sec. 11, T. 10 N., R. 9 E.; on G. W. Edwards's land, in sec. 18, T. 10 N., R. 9 E.; on Mr. Dulaney's land, in sec. 9, T. 9 N., R. 9 E.; also on M. L. Reed's land at Tilden. At the latter place it is 20 inches thick and when freshly dug from the bank is of a jet-black color.

The Tuscaloosa clays of southeastern Itawamba County have been utilized for years in making stoneware. These clays are of a bluish and in places pinkish color, and are interbedded with sandstone and less pure clays. The clay used by the Davidson pottery comes just above a ledge of sandstone which is but a few inches thick.

### EUTAW SANDS.

Immediately overlying the Tuscaloosa and underlying the Selma chalk is the Eutaw formation, which is typically exposed at Eutaw, Ala. Hilgard described the upper part of this formation under the name of Tombigbee sands.

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[a] Hilgard, E. W., Geology and Agriculture of Mississippi, 1860, p. 67.

The characteristic material of the Eutaw consists of fine-grained micaceous sands, calcareous in the upper part, with more or less glauconite or greensand. Irregular beds of sandy clays are not infrequent. The lowest division is largely composed of highly cross-bedded sands of various colors, such as orange, red, blue, and deep yellow. This lower part is distinguished with difficulty from the upper Tuscaloosa, and the line between the two formations is therefore arbitrarily drawn.

The irregularity in the deposition of the lower Eutaw is well marked along upper Tombigbee River and its tributaries and also along the streams in Alabama. No one stratum of sand or clay can be traced continuously for any great distance. A bed of clay 8 or 10 feet thick may thin out in as many rods and entirely disappear.

A well at Eutaw, Ala., reached the clays of the Tuscaloosa formation at a depth of 400 feet. The wells at Columbus, Miss., obtain water below the first clay of the Tuscaloosa at a depth of about 300 feet. Columbus is located on the western edge of the Eutaw formation and the wells therefore pass through its entire thickness, which here is less than 300 feet. At the northern border of the State the formation is much thinner. The combined thickness of the Eutaw and the underlying Tuscaloosa at Corinth, Miss., is less than 375 feet, while in western Alabama it is 900 to 1,000 feet. At Corinth the top of the Eutaw was reached at a depth of about 90 feet and the hard Paleozoic rocks at 450 feet. If the two formations thin proportionally the Eutaw here would be about 90 feet and the Tuscaloosa 270 feet thick. A record of the well was kept, but the driller failed to notice any change in passing from the Eutaw to the Tuscaloosa.

The area occupied by the Eutaw consists of a narrow band of territory 5 to 12 miles wide, lying just east of Tombigbee River in Monroe and Lowndes counties, and on the west side of the river north of this, extending through eastern Lee, east-central Prentiss, and eastern Alcorn counties.

The change from the sandy Eutaw formation to the overlying Selma chalk is not an abrupt stratigraphic break. On the contrary, there is a gradual change from the upper members of the Eutaw to the lower division of the Selma. It is so gradual that experienced well drillers often fail to distinguish the line of contact between the two formations. The upper Eutaw contains a large amount of carbonate of lime, greensand, and a fauna greatly resembling that of the Selma chalk.

The section given below offers an excellent opportunity for studying the transition beds between the Selma and Eutaw. At a distance of 4 miles above Columbus, on Tombigbee River, the bluff on the west side reaches about the same height as the hill on which Columbus is built. For a distance of 1 mile along the river the cliff exposes a fine section of the upper Eutaw and the basal beds of the Selma. West of the river the Selma prairies slope gently to the top of the bluff and then suddenly descend 40 to 50 feet to the water's edge. The east side of the river is a level bottom but little above the river. At the town of Columbus there are high bluffs on the east side and a wide bottom on the west side of the river. The same black prairie soils of the Selma, which come within 3 miles of the river due west of Columbus, extend to the high bluff along the river 4 miles above town. The following section was obtained in the bluff where the dirt road comes down to the river:

*Section on Tombigbee River 4 miles north of Columbus.*

| | Ft. | In. |
|---|---|---|
| 11. Lafayette. | | |
| 10. White to gray joint clay of the Selma, containing less sand at the top than at the bottom. In the unweathered condition the clay is of a pale-blue color, containing green and black sand | 8 | |
| 9. Greensand, unconsolidated, highly calcareous, and containing numerous large oyster shells | 5 | |
| 8. Ledge of indurated greensand, calcareous, with large oyster shells. This ledge, being harder than the stratum above, stands out more distinctly and from a distance looks very much like a hard, compact ledge of limestone | | 12 |
| 7. Lighter colored unconsolidated sand containing a few very small fossils and no large ones | 1 | 2 |
| 6. Greensand, nonfossiliferous | | 6 |
| 5. Slightly fossiliferous, gray micaceous sand | 5 | |
| 4. Ledge of indurated sand, slightly fossiliferous | | 10 |
| 3. Greensand, unconsolidated | 4 | |
| 2. Ledge of indurated sand | | 8 |
| 1. Fossiliferous greensand to water's edge | 4 | |

The material at the water's edge is identical with the greensand in the bluff above the bridge at Columbus and belongs to the Eutaw formation. The upper part of the bluff represents the "blue rock" of the Selma. A deep gully a few yards to the north has a continuous section of the Selma from the top of the Eutaw to the Selma prairie soil. The contact between the Eutaw and Selma is therefore shown in the section given above. Nos. 1 to 9, inclusive, mark the sandy phase of the Eutaw, and No. 10 the clayey portion of the Selma, containing more or less sand.

The above section is at or near the locality mentioned by Hilgard in his Geology and Agriculture of Mississippi, page 74, where many fossils were collected by Dr. William Spillman, of Columbus, from the upper part of the "Tombigbee sand." A list of the fossils as identified by Spillman is published in the report just cited, page 389. According to this list the fauna is somewhat closely related to that of the overlying Selma and Ripley formations, many of the species cited ranging to the top of the Ripley, but at least one of the ammonite species belongs to a generic type that is not known above the horizon of the Eutaw. There seems to be a gradual transition, both lithologically and faunally, from the upper calcareous sands of the Eutaw to the lower division of the Selma.

The underlying larger portion of the Eutaw has yielded very few fossils other than lignitized wood, but at a few places in Alabama species of *Exogyra, Ostrea, Anomia, Placenticera*, etc., have been found.

The line of contact between the Eutaw and the overlying Selma at the Alabama line is near Tombigbee River, which practically forms the boundary between the two formations south of Columbus. Near the mouth of James Creek, in the northeast corner of Noxubee County, the greensands of the upper Eutaw are exposed at intervals for 2 miles or more along Tombigbee River. James Creek has cut its channel into these greensand beds. The east bank of the Tombigbee also shows a 10-foot section of the same greensand beds, which here contain a large amount of clay.

The following section on the Southern Railway 3½ miles east of Corinth shows the contact between the upper Eutaw and the Selma chalk:

*Section on Southern Railway 3½ miles east of Corinth.*

| | Feet. |
|---|---|
| 4. Lafayette sands | 6 |
| 3. Joint clay, bluish when fresh | 4½ |
| 2. Green calcareous sand, very fossiliferous, thinning to the east | 7 |
| 1. Yellow calcareous coarse-grained sand, with thin ledge of indurated sandstone | 8 |

In the branch to the west the coarse greensands of the Selma are present at a lower elevation than No. 1 of the above section. The strata here dip to the east, or in an opposite direction to the general dip of the district. The base of the greensand stratum, No. 2, at the west end of the cut is 4 feet above the railroad track. At a distance of 800 feet to the east the top of this stratum has dipped below track level.

The country to the east of the Eutaw-Selma contact is hilly; that to the west is rolling or level. The western edge of the Eutaw can be traced southwest from the above section by a line of hills which form a sharp contrast to the level or rolling country of the Selma prairies to the west.

Three miles south of Corinth in a deep cut on the Mobile and Ohio Railroad the following section, which is very similar to the one given above, is exposed:

*Section on Mobile and Ohio Railroad 3 miles south of Corinth.*

| | Ft. | In. |
|---|---|---|
| 8. Lafayette sands capping hills | 8 | 10 |
| 7. Gray joint clay containing large oyster shells | 5 | |
| 6. Greensand containing same fossils as No. 7 | 5 | |
| 5. Indurated calcareous sand, yellow at bottom and passing into deep-yellow, coarse, sharp-grained sand with few fossils | 3 | 6 |
| 4. Unconsolidated greensand, noncalcareous | 1 | 6 |
| 3. Unconsolidated yellow sand, noncalcareous | 1 | 2 |
| 2. Greensand, noncalcareous | 1 | 6 |
| 1. Pale greensand, becoming a deeper green at bottom of cut. In the branch below this sand alternates with thin bands of clay | 5 | |

The following interesting and instructive section of the Corinth waterworks well was obtained from the waterworks company:

*Record of waterworks well, Corinth.*

| | | Feet. |
|---|---|---|
| Selma chalk | Common soil | 15 |
| | Blue clay | 20 |
| | Sand | 30 |
| | Hard rock | 1 |
| Eutaw and Tuscaloosa | Sand, water bearing, supplying the shallow wells | 35 |
| | From 100 to 300 feet the strata are mostly hard "shale" clay, alternating with beds of fine sand, which will furnish 225 gallons of water per minute with deep-well pumps; supply seems to be constant; water stands at top of casing | 200 |
| Carboniferous, including Chester and St. Louis. | From 300 to 435 feet nothing but sandstone, limestone, and shale, with iron pyrite, but no water | 135 |
| Tullahoma flint, at base of which is found the fire clay which occurs at the base of the Tullahoma along Tennessee River. | From 435 to 550 feet passed through gravel or "rock silica" at the base of which was good fire clay | 115 |
| | | 551 |

The well stopped in the fire-clay bed at the base of the Tullahoma. This section gives the most accurate and reliable data obtainable on the thicknesses of the different formations.

There is a decided thinning of all the formations from south to north. The Selma, which Smith has estimated to be 930 to 1,200 feet thick in western Alabama, has thinned to 100 feet at Corinth. The Tuscaloosa and Eutaw taken together have a thickness in the Corinth well of only 200 feet, while Smith has estimated the Tuscaloosa alone to be 900 to 1,000 feet thick in western Alabama.

## SELMA CHALK.

The subdivision of the Cretaceous immediately overlying the Eutaw formation is the Selma chalk. It was called "Rotten limestone" by Hilgard, but the name has since been discarded for that of the locality where it is typically exposed—Selma, Ala.—this name being first used by Dr. E. A. Smith of the Alabama Geological Survey.

The Selma chalk is a mass of loosely semicemented lime carbonate of exceptional purity, and where typically exposed along the larger streams it has a white appearance and is called the "white chalk" bluffs. To the casual observer the entire formation has much the same appearance, but it may be separated into three natural divisions, based primarily on chemical analysis—(a) the sandy transition beds at the base, (b) the "blue rock," or more clayey unweathered portion, and (c) the "rotten limestone," or chalk, including the upper portion of the formation.

(a) The lowest division contains a large amount of free sand which was washed into the Selma sea from the Eutaw and older land surface to the east. This forms the transition beds from the extremely sandy portion of the Eutaw to the deep-sea deposits of lime carbonate which characterize the Selma chalk. The amount of sand is greatest near the base and becomes less and less upward until it finally disappears entirely.

(b) The middle portion contains a large amount of clay and when freshly dug is of a bluish color. It is found in the deep wells and is known and recognized by the drillers as "blue rock." The great amount of clay in the lime carbonate renders the rock impervious to water. The fine supply of artesian water stored in the Eutaw reservoir is held in place by the "blue rock" of the Selma. It is on account, therefore, of this impervious bed overlying the Eutaw that so many artesian wells are available over the Selma area.

(c) The uppermost division contains a greater amount of lime carbonate and much less clay than the "blue rock" and likewise a smaller amount of free silica than the lowest division. Some of the analyses of this chalk show 98 per cent calcium carbonate.

In places a hard crystalline limestone, somewhat silicified, forms a capping to some of the hills of the upper Selma. Hard flint rock and thin strata of sandstone are reported in the deep-well boring at Livingston, Ala.

Fossils are more or less abundant throughout the formation. *Ostrea*, *Gryphæa*, and *Exogyra* are almost always present, and numerous other forms occur in the upper and lower subdivisions. Below is a list of the Selma fossils reported from Mississippi by Dr. T. W. Stanton. In speaking of these fossils Stanton remarks:

> The list of fossils from the Selma or "Rotten limestone" is based on a small collection from Starkville received from you and a somewhat larger collection obtained by myself at Houston. Both these localities are comparatively near the contact of the Selma with the Eocene in an area where the Ripley as such does not appear. From this fact and from the close resemblance of the faunas, which would apparently be more striking if the condition of the fossils would permit the identification of all the species present, I am inclined to believe that the so-called "Rotten limestone" of these localities is really equivalent to a part of the Ripley farther north. Hilgard[a] mentions similar occurrences in Noxubee and Kemper counties.
>
> It is very probable that thorough systematic collecting in the Selma would show some distinctive species. The rare fossils mentioned by Hilgard as *Radiolites* and "*Ichtyosarculites*" and several of the genera of fishes and other vertebrates have not been reported from the Ripley, but their presence is probably due to the difference in physical conditions rather than to difference in age. It will be noticed that a few of the invertebrates in the following list do not appear in the Ripley list, but nearly all of these species are elsewhere found in the Ripley.

*Fossils from the Selma chalk at Houston and Starkville.*

Hemiaster.
Terebratulina.
Ostrea larva Lamarck.
Ostrea vomer Morton.
Exogyra costata Say.
Gryphæa vesicularis Lamarck.
Anomia argentaria Morton.
Plicatula saffordi Conrad.
Dianchora echinata (Morton).
Pecten quinquecostata Sowerby?.
Pecten venustus Morton.
Lima acutilineata Conrad.
Lithophagus ripleyanus Gabb.
Nemodon eufalensis (Gabb).
Cucullæa vulgaris Morton.
Nucula perequalis Conrad.
Leda longifrons Conrad.
Trigonia thoracica Morton.
Crassatella.
Cardium.
Veniella conradi Morton.
Legumen planulatum Conrad.
Liopistha protexta (Conrad).
Liopistha (Cymella) bella Conrad.
Gastrochæna americana Gabb?.
Scala sillimani (Morton).
Scala annulata (Morton).
Turritella.
Xenophora umbilicata (Tuomey).
Pugnellus densatus Conrad.
Gyrodes petrosa (Morton).
Perissolax octolirata (Conrad).
Pyropsis.
Rostellites.
Volutomorpha.
Nautilus dekayi Morton.
Baculites anceps Lamarck.
Scaphites conradi (Morton).
Placenticeras.
Belemnitella americana (Morton).

The thickness of the Selma as determined by many deep-well borings throughout the region is found to vary from 350 feet near the Tennessee line to 1,000 feet at Starkville and to over 1,200 feet just across the State line in Alabama.

The area of the outcropping Selma is a level or rolling prairie, well adapted to agriculture. It is everywhere marked by a rich black prairie soil, which is readily formed from the underlying limestone. It embraces the large part of Noxubee, western Lowndes, eastern Oktibbeha, the larger part of Clay, western Monroe, eastern half of Chickasaw, almost all of Lee, western Prentiss, and central Alcorn counties. The west line of outcrop can be traced approximately through Scooba, Flatwood, and a point 3 miles west of Starkville to Houston. From this place the line bends more to the east, passing through Troy, Blue Springs, Graham, Antioch, and a point 2 miles west of Kossuth to the Tennessee line.

A description of the contact between the lower Selma and the underlying Utah, as shown in the river bluff 4 miles above Columbus, is given under the Eutaw formation (p. 14). At the above-mentioned place the ledges of indurated greensand carrying Eutaw fossils gradually change to the blue argillaceous joint clay of the Selma. A short distance west of the river the typical black prairie soils of the Selma come to the surface.

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[a] Geology and Agriculture of Mississippi, 1860, p. 82.

At the big oxbow bend in Oaknoxubee River, one-fourth mile below the wagon bridge at Macon, the river has formed on its south side a bluff 75 feet high (Pl. III, *A*). This bluff shows a solid mass of white or slightly yellow limestone, nonfossiliferous and apparently without bedding planes, but in a view from a distance the stratification of the material is apparent from the fact that the unequal hardness of the strata has caused some to weather more rapidly than others. There is a marked dip to the south. This same limestone outcrops in all the smaller streams flowing into the Oaknoxubee from Macon to the Alabama border. It is a part of the upper subdivision of the Selma. Still farther west the prairies and hillsides from which the soil has been removed are covered with large oyster shells which have given rise to the term "shell land."

There is a striking difference in the character of the general topography and vegetation of the Selma chalk and the overlying Porters Creek clays. The cold, gray, and apparently lifeless soils of the Porters Creek produce a growth of short-leaf pine which does not appear on the black calcareous soils of the Selma. In some of the abandoned fields of the Selma, where there is a thin veneering of Lafayette, there is more or less pine, particularly along the edges of the Selma, but pine is not native to these soils. Black, white, and post oak, with some hickory, poplar, gum, and walnut, are the principal timbers of this formation.

On the west side of Quilby Creek, where it runs south along the State line between Alabama and Mississippi, 7 miles east of Sucarnochee, Miss., the Selma chalk forms a small bluff. The prairie soil extends back 2 miles farther west and is overlain by the Porters Creek clay. On the east side of the creek, about 100 yards east of the Alabama line, the Selma forms a bluff somewhat higher than on the opposite side in Mississippi. The top of the bluff is capped by a coarse-grained sandstone, cemented by lime carbonate, and this doubtless represents the lowest member of the Ripley, which is present in Alabama but wedges out in southeastern Mississippi. The sandstone contains large, round lime concretions the size of the closed hand.

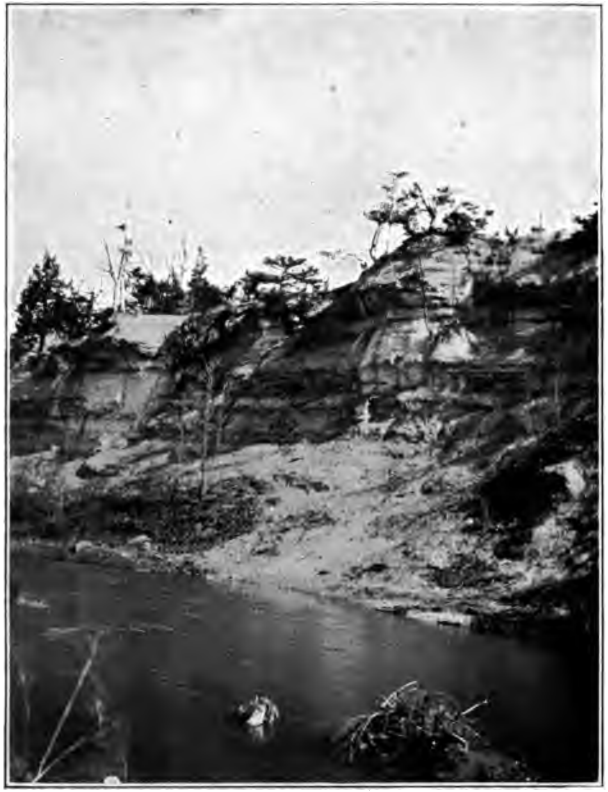
Three miles north of Scooba the western border of the Selma chalk outcrop is seen in a series of hills forming the south bank of Wahalak Creek. The bottom of the creek here is about 1½ miles wide, with the steeper slope on the south side. The creek has channeled its bed into the white Selma chalk, which outcrops continuously throughout its course. The limestone occurs in the bed of the creek to a point 6½ or 7 miles northwest of Wahalak, but the overlying Porters Creek clay is present on the higher land on both sides of the creek.

On the low range of hills south of Wahalak Creek, beginning near the Mobile and Ohio Railroad track and extending eastward, is a bed of sand rock 10 feet thick capping the tops of the hills. It is a coarse-grained sandstone cemented with lime carbonate and contains numerous little bivalve shells. It is similar to sandstone found 7 miles east of Sucarnochee and doubtless represents the lowest beds of the Ripley formation.

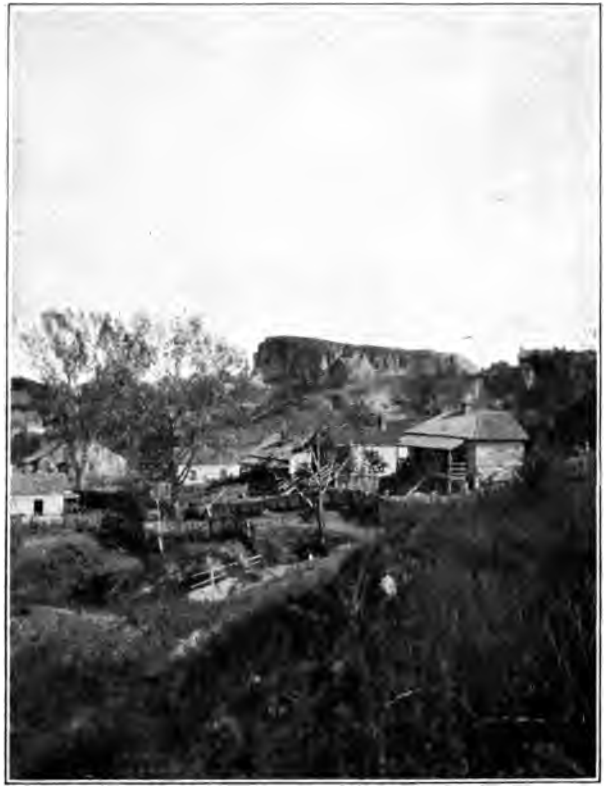
In the vicinity of Prairie Rock there is a hard crystalline limestone, or "flint rock," very different from the soft chalk-like limestone along the river at Macon. This so-called "flint rock" has been used for road metal and foundations for houses, but the readiness with which it breaks down under the action of weathering agents renders it unsuitable for such purposes.

Men familiar with the districts say that the hard flinty limestone is rarely more than 4 feet thick, and always occurs near the surface. Below this hard stratum comes the soft, whiter "rotten limestone," which is, on an average, 20 feet thick and is underlain by the "blue rock." Cisterns are always dug to the "blue rock," which requires no curbing.

There are two distinct soils in the Selma area, giving rise respectively to "the post-oak" land and the "prairie" proper. The former is the highest land between the stream divides, which has suffered but little erosion. It is a very level table-land, sloping gently to the streams. This post-oak land is covered with a thin veneering of Lafayette loam, rarely more than 10 feet thick. It has a growth of post oak and some scrubby black-oak timber. The "prairie" land is that from which the Lafayette has been removed, so that the rich



*A*. SELMA CHALK BLUFF, MACON.



*B*. LOESS BLUFF. YAZOO CITY.

black loam, formed from the decomposition of the Selma chalk, is at the surface. This land lies along the slopes or more rolling areas where erosion has been more rapid.

When the country was first settled the black prairie soil was too strong for cotton. It produced a large stalk, but little lint. Until recent years all the cotton was planted on the poorer post-oak soils and the prairie lands were put in corn. After years of continuous crops of corn the prairie lands became the best cotton lands and now the principal part of the cotton is planted on these richer soils. In fact, the thinner post-oak soils in places have been abandoned for cultivation and are used only for pasturage.

At Cliftonville, in northeastern Noxubee County, there is a thin stratum 4 to 6 feet thick of hard crystalline limestone similar to that at Prairie Rock. It forms a mesa-like capping to the hills in this vicinity. It is locally known as "lime rock," in distinction from the "blue rock" below.

The blue rock of northeastern Noxubee County is the lower subdivision of the Selma. It is very rich in lime carbonate and breaks down into a black, easily cultivated, fertile soil which produces more cotton and corn to the acre than any other land of the State. The higher interstream areas to the west are covered with the post-oak clay soil.

The sands of the Eutaw formation extend 2 miles west of Aberdeen and the post-oak clay soils of the Selma chalk continue westward nearly to the main line of the Mobile and Ohio Railroad. Over a large area in central Monroe County the Selma rarely appears at the surface, but is always found in wells and cisterns and along the railroad excavations. One mile south of Strongs the Illinois Central Railroad has cut into the Selma to a depth of 15 feet.

The width of the Selma area is greatest in Monroe and Chickasaw counties, in the latitude of Houston. From this locality northward the outcrop becomes narrower and the formation thinner. Wells near Rienzi, Corinth, and Wenasoga, Miss., and Chewalla, Tenn., show a gradual thinning of the Selma to the north, and it finally disappears completely near Camden, Tenn.

## RIPLEY FORMATION.

Immediately above the Selma chalk comes the uppermost division of the Cretaceous, which has been called Ripley, from its typical exposure near Ripley, Miss. The materials composing this formation are alternating beds of coarse-grained sandstones, limestones, clays, unconsolidated sands, phosphatic greensands, and marls. The deep, quiet sea in which the great thickness of the homogeneous Selma limestone was deposited became more changeable at the beginning of Ripley time. The character of the Ripley deposits marks the transition period from the deep, marine deposits of the Selma to the shallow, near-shore deposits of the early Tertiary, in which the predominating materials are sand and clays.

The thickness of the formation, estimated from the width of outcrop, with a westward dip of 15 feet per mile, reaches a maximum of 280 feet.

There is a marked change in topography from the rolling prairies of the Selma to the steep hills of the Ripley. The area of the latter is much smaller than that of the Selma. It is widest at the north in Tippah County, gradually narrowing to the south, and wedging out altogether at Houston, Chickasaw County. To the south the Ripley is well marked in Alabama, but wedges out in Kemper County, Miss., near Shuqualak. Between this town and Houston the Ripley in most places is absent, and when present occurs as outliers.

Prof. W. N. Logan, of the Agricultural and Mechanical College of Mississippi, in his Geology of Oktibbeha County, page 30, describes three outliers of phosphatic greensand and bluish and yellowish micaceous marl which he refers to the Ripley. *Exogyra costata, Ostrea falcata, Gryphæa convexa, Pecten quinquecostatus*, and *Placuna scabra* are found in the marls. Doubtless more detailed work in the various counties along the western border of the Selma area would reveal a large number of similar Ripley outcrops.

The Ripley beds in Mississippi have not received sufficient study and detailed work to determine accurately the relative succession of strata. At New Albany and Ecru, which are located along the western edge of the formation in Union and Pontotoc counties, there are some well records which show the succession of strata of the upper and middle portions of the formation. The well at New Albany doubtless reaches the water-bearing sand near the base of the formation. The following is the record of this well, as given by the driller, Mr. Baker:

*Record of well at New Albany.*

| | Feet. |
|---|---|
| Surface clay | 20 |
| Sandstone | 4 |
| Clayey sand, water bearing | 15 |
| Blue marl containing shells, with occasional beds of limestone 3 to 4 feet thick | 165 |
| Hard stratum of limestone coming just above water | ½ |
| White sand, source of water | 20 |

The following accurate log was kept of the railroad well at Ecru, Pontotoc County, by the driller, Albert Goldsbury:

*Record of well at Ecru.*

| | Feet. |
|---|---|
| Red clay and loam | 23 |
| Blue clay | 27 |
| Hard limestone | 4 |
| Reddish, muddy sand | 5 |
| Bed of fossiliferous marl | 1 |
| Sand | 3 |
| Reddish sand containing shells, water bearing | 10 |
| Compact clay, bottom of well. | |

One-half mile west of Ecru, on the west bank of the creek, is a hard ledge of limestone, but slightly fossiliferous, which is underlain by a softer limestone of a white to gray color. Three miles west of town, on Clay Lemon's place, occurs a coarse-grained sandstone which belongs to the upper Midway group.

The classic locality for the Ripley formation is in the "bluffs of Owl Creek, 3 miles northeast of the town of Ripley,"[a] Tippah County. The locality one-half mile south of town, on the south side of Ripley Creek, was referred to the Ripley formation by Hilgard and so mapped; but a more thorough study of the fossils by Harris and others has placed the persistent hard limestone teeming with *Turritella mortoni* in the lowest member of the Midway, of Tertiary age. This Turritella rock, in the vicinity of Ripley and along many of the streams for 3 miles east, overlies the "Owl Creek" marl, which is of undoubted Ripley age.

The same order of strata as found east of Ripley continues northward into Tennessee. At Chalybeate Spring, 2½ miles east of Walnut, the upper member of the Cretaceous, the Owl Creek marl, is overlain by the Turritella rock of the Midway. This marl is dark blue and micaceous, and contains in places remarkably well-preserved fossils.

A list of the Ripley fauna is given below. The collection was made and the fossils determined by Dr. T. W. Stanton. In speaking of the Ripley fauna, Stanton adds:

> The Ripley list is based on collections obtained by myself in Tippah County, Miss., in 1889. The most thorough collecting was done along the Owl Creek bluff about 3 miles from Ripley, where the original Ripley fauna described by Conrad was obtained. It must be considered the type locality for the Ripley formation and it yielded fully 90 per cent of all the species here listed. The collection contains a considerable number of undescribed or unidentified species which are not mentioned in the list. Many synonyms and doubtful forms are also omitted.

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[a] See Jour. Acad. Nat. Sci. Phila., 2d ser., vol. 3, 1858, p. 324.

*Ripley fossils from Tippah County.*

Cassidulus subquadratus Conrad.
Cassidulus subconicus Clark.
Hamulus onyx Morton.
Ostrea tecticosta Gabb.
Ostrea plumosa Morton.
Ostrea subspatulata Forbes.
Exogyra costata Say.
Anomia argentaria Morton.
Lima acutilineata Conrad.
Lima reticulata Forbes.
Pecten quinquenarius Conrad.
Camptonectes argillensis Conrad.
Camptonectes parvus Whitfield.
Syncyclonema simplica Conrad.
Syncyclonema conradi (Whitfield).
Gervilliopsis ensiformis (Conrad).
Inoceramus argenteus Conrad.
Inoceramus cripsi var. barabini Morton.
Inoceramus sagensis Owen.
Inoceramus proximus Tuomey.
Pulvinites argentea Conrad.
Dreissena tippana Conrad.
Crenella serica Conrad.
Pinna laqueata Conrad.
Cucullæa vulgaris Morton.
Nemodon eufalensis (Gabb).
Nemodon brevifrons Conrad.
Pectunculus subaustralis d'Orbigny.
Nucula cuneifrons Conrad.
Nucula percrassa Conrad.
Nucula slackiana Gabb.
Leda longifrons Conrad.
Leda pinnaformis Gabb.
Leda protexta Gabb.
Trigonia angulicosta Gabb.
Trigonia eufalensis Gabb.
Trigonia thoracica Morton.
Vetericardia crenalirata Conrad.
Crassatella vadosa Morton.
Crassatella pteropsis Conrad.
Cardium alabamense Gabb.
Cardium dumosum Conrad.
Cardium tippanum Conrad.
Cardium eufaulense Conrad.
Pachycardium spillmani Conrad.
Veniella conradi Morton.
Cyprimeria depressa Conrad.
Cyprimeria alta Conrad.
Aphrodina tippana Conrad.
Tenea pinguis Conrad.
Ænona eufaulensis Conrad.
Tellimera eborea Conrad.
Linearia metastriata Conrad.
Gari elliptica Gabb.
Solyma lineolata Conrad.
Legumen planulatum (Conrad).
Leptosolen biplicata Conrad.
Panopæa decisa Conrad.
Pholadomya occidentalis Morton.
Anatimya anteradiata Conrad.
Anatimya postsulcata Conrad.
Liopistha protexta (Conrad).
Veleda lintea Conrad.
Cuspidaria moreauensis (Meek and Hayden)?
Corbula crassiplica Gabb.
Corbula perbrevis Conrad.
Corbula subcompressa Gabb?
Gastrochæna americana Gabb.
Pholas cithara Morton.
Diploconcha cretacea Conrad.
Dentalium ripleyanum Gabb.
Scala sillimani (Morton).
Turritella vertebroides Morton.
Turritella tippana Conrad.
Turritella trilira Conrad.
Laxispira lumbricalis Gabb.
Trichotropis cancellaria Conrad.
Lunatia obliquata Hall and Meek.
Gyrodes crenata Conrad.
Gyrodes petrosa Morton.
Anchura abrupta Conrad.
Anchura rostrata (Gabb).
Anchura decemlirata Conrad.
Pterocerella tippana (Conrad).
Pugnellus densatus Conrad.
Pyrifusus bellaliratus Conrad.
Pyrifusus subdensatus Conrad.
Fusus holmesianus Gabb.
Fusus tippanus Conrad.
Strepsidura interrupta (Conrad).
Perissolax octolirata (Conrad).
Pyropsis perlata Conrad.
Liopeplum cretaceum (Conrad).
Liopeplum canalis (Conrad).
Liopeplum subjugosum (Gabb).
Liopeplum leidermum (Conrad).
Volutomorpha eufalensis (Conrad).
Rostellites navarroensis (Shumard).
Nautilus dekayi Morton.
Baculites ovatus Say
Baculites anceps Lamarck.
Scaphites conradi Morton.
Turrilites alternatus Tuomey.
Sphenodiscus lenticularis (Owen).

The character of the lower Ripley is shown in the hills near Ellistown. These hills, bordering on the Selma chalk area, rise 150 feet or more above the prairie lands to the east. The following section shows the succession of strata on the Ellistown and Ripley road in sec. 21, T. 7 S., R. 4 E., in eastern Union County:

*Section of Ripley formation near Ellistown.*

| | Feet. |
|---|---|
| 4. Lafayette capping top of hills. | |
| 3. Yellowish, micaceous, coarse-grained sand | 20-30 |
| 2. Laminated clayey shale | 5-10 |
| 1. Limestone ledge of unknown thickness. | |

This limestone is sufficiently pure for making lime, and is used locally for building purposes. The strata below the ledge of limestone are covered with the wash of the hillside, and the thickness can not be determined.

South of Ellistown the blue calcareous clay which perhaps belongs to the Selma appears up the hillside 25 feet above the bottom land to the east.

## TERTIARY.

### MIDWAY GROUP.

#### CLAYTON FORMATION.

The lowest division of the Tertiary is represented in Mississippi by a series of hard crystalline limestones and calcareous sandy marls, belonging to the Clayton. The limestone of this formation was referred by Hilgard to the Ripley. More recent investigation, however, by Harris, Aldrich, and others has, on paleontologic grounds, placed the limestone in the lowest division of the Tertiary.

The Clayton formation in Mississippi is represented by about 30 to 40 feet of limestone and 30 feet of sandy marl. Owing to the limited area of the Clayton and the lack of detailed work across the State it has been mapped with the overlying Porters Creek clay, which is shown as a narrow belt extending from Alabama to Tennessee and lying between the Ripley and Selma on the east and the Wilcox on the west. The name Midway is given to the group from the type locality at Midway, Ala.

The Clayton is well shown in Tippah and Union counties, where it has received the most detailed study. Its lowest member is a hard blue limestone containing a large number of fossils, the most prominent of which is *Turritella mortoni*. For this reason this rock has been called the Turritella limestone. On Mr. Bobo's place, 1½ miles north of Chalybeate, the Turritella rock is little more than a conglomerate of angular fragments of gray, white, and yellow limestone cemented together. *Turritella* fossils make up a large part of the limestone. Throughout the whole mass are small, rounded, and often glazed iron pebbles reaching one-fourth inch in diameter. This limestone rests on the dark-blue "Owl Creek" marl of the Ripley and is overlain by a yellow sandy marl. The hard persistent Turritella rock is found in numerous branches in the vicinity of Chalybeate and southward to Ripley. Two and a half miles east of Ripley it forms in places small bluffs along the streams.

The Clayton limestone outcrops on the south side of Ripley Creek one-half mile south of Ripley. The same ledge occurs along the creek for 1 mile or more to the east. It is here underlain by a yellow, highly micaceous, arenaceous marl containing a few badly preserved fossils. The yellow color is due to oxidation by surface agencies, for a few feet below the surface the color becomes a dark blue.

One-half mile east of the bridge across Ripley Creek south of town the Turritella limestone of the Clayton forms a bluff 20 to 40 feet high. The following section gives the relation of the materials immediately overlying the Turritella rock:

*Section of Clayton formation near Ripley.*

| | Ft. | In. |
|---|---|---|
| 4. Lafayette capping hill. | | |
| 3. Thin stratum of green calcareous sandstone, very hard and containing large flakes of mica and few fossils | 2 | 2 |
| 2. Yellow micaceous sand | 30 | |
| 1. Turritella limestone | 15 | |

No. 1 of the above section is found in the wells at Ripley from 10 to 35 feet below the surface. At the mill in the bottom on the east side of town a well recently dug has the dark-blue "Owl Creek" marl on the dump. The yellow sand overlying the Turritella rock is very persistent and is easily distinguished from the overlying Lafayette where the latter is present. When damp the yellow sand has a slight greenish tinge. This sand is present along many of the streets of Ripley, especially on the lower streets near the depot. In the northern part of the town, near the "city limit," the greenish-yellow sand outcrops on

Main street and in the gullies east of the street. Here the same relations exist as at the hill one-half mile east of the bridge mentioned above.

The thin ledge of hard green calcareous sandstone on top of the yellow sand has more the appearance of a limestone. Its thickness is 24 to 26 inches.

Two and a half miles east of Ripley, on the Ripley and Boonville road, the Clayton limestone occurs in a deep ravine, as shown in the following section. Some distance down the creek the "Owl Creek" marl occurs at a lower elevation.

*Section of Clayton limestone 2½ miles east of Ripley.*

| | Ft. | In. |
|---|---|---|
| 6. Greenish-yellow sand, similar to that at Ripley | 10 | |
| 5. Upper stratum of hard limestone with large *Turritella* fossils | 1 | 3 |
| 4. Yellow to gray marl containing numerous large *Turritella* | | 20 |
| 3. Hard flinty limestone with no *Turritella*, but containing a small branching coral | | 26 |
| 2. Indurated marl containing large *Turritella* | | 12 |
| 1. Lowest stratum visible is the Turritella rock, which here is made up almost entirely of these fossils | | 42 |

The same Turritella limestone that is found 2½ miles east of Ripley shows in many ravines east of Muddy Creek in the vicinity of Chalybeate. At a few places, as at Chalybeate Spring, the underlying Ripley marl is exposed. The limestone occurs as ledges from 3 to 6 feet thick. On Mr. Bobo's place, 1½ miles north of Chalybeate, the limestone is overlain by about 30 feet of yellow sandy marl containing numerous fragile fossils. At the top of the yellow sandy marl is a thin band of green sandstone containing mica. The order of strata here is the same as it is at Ripley, and the materials are but little different in general lithologic character.

The most complete list of fossils from the Midway group in Mississippi is given by G. D. Harris in American Paleontology, No. 4, pages 22-25.

## PORTERS CREEK CLAY.

This formation was described by Doctor Hilgard in his Geology and Agriculture of Mississippi under the term Flatwoods clays. It is known in Alabama as the Black Bluff or Sucarnochee series, and was described by Safford of Tennessee as Porters Creek. The term Porters Creek as used by Safford has priority of date and has therefore been adopted by the United States Geological Survey.

The Porters Creek clay is traceable across western Kentucky, Tennessee, and Mississippi, and as far east as Alabama River in Alabama.

The area in Mississippi is a narrow belt from 2 to 15 miles wide, extending across northeastern Kemper, southwestern and western Noxubee, northeastern Winston, western Oktibbeha, Clay, and Chickasaw, west-central Pontotoc and Union, and western Tippah counties. The typical "Flatwoods" is characterized throughout the State by low, flat land resembling the broad bottom of a large river. In many places the country is still uncleared and is everywhere known as the "Flatwoods country."

The material of the Porters Creek formation in the lower part is principally a dark-gray joint clay, overlain by a coarse-grained micaceous sandstone containing large fossils. Occasionally it weathers almost white; and in places it is a black slaty clay, bearing fossils.[a] In places the clay contains bodies of micaceous sandstone that seem to have been segregated into horizontal sheets and vertical masses, many of which have the appearance of small dikes. It is quite possible that small fissures have been made in the clay by earthquakes and subsequently filled with micaceous sand.

Hilgard[b] in describing the physical properties of the Porters Creek or "Flatwoods" clays, says:

> This Flatwoods clay does not "readily dissolve" or form a plastic paste with water; but whenever by dint of repeated kneading (such as the wheels of vehicles will perform) it has been made to form a paste, its tenacity is such as to be scarcely exceeded by the most approved "prairie mud." Nor can the black

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[a] Coastal Plain of Alabama, p. 186.

[b] Geology and Agriculture of Mississippi, 1860, p. 275.

prairies of Pontotoc and Monroe, during the wet season, present more formidable obstacles to the wagoner than do the bottoms and hillsides of the Flatwoods region. Hence the great frequency among its streams of such names as Mud Creek and others still more eloquently expressive of the awe in which they are held by those who are habitually obliged to traverse the Flatwoods.

There are no wells to the writer's knowledge, which have been dug through the Porters Creek, nor any rivers crossing at a right angle to the strike of the formation, by which to determine its thickness. Estimated from the width of outcrop, with a westward dip of 15 feet to the mile and a maximum width of outcrop of 14 miles, the thickness, is 210 feet. The more probable thickness, as observed from surface outcrops in Tippah County, is about 100 feet.

On the road leading northwest from Ripley the gray Porters Creek clay is present to the top of the hill 1¼ miles northwest of town, also 2½ miles north of town and at various places along the railroad between Ripley and Walnut. Its thickness, as measured on the hill northwest of Ripley, is 75 feet.

One-half mile north of Walnut the gray, lead-colored clay, which at Ripley rests on the thin band of sandstone and is 34 feet above the top of the Turritella rock, outcrops in the deep ravine south of the railroad water tank. The same clay outcrop continues along the track one-half mile north of the water tank.

West of Walnut the hills rise 100 feet or more above the lowlands along the streams. On some of the hillsides the surface soil has been removed by heavy rains, and a more complete section of the Lower Eocene strata is exposed. One mile west-southwest of Walnut the same gray, lead-colored clay as that in Ripley and at the water tank north of Walnut shows on the steep hillside just south of a little stream flowing eastward, to a height of 40 feet above the stream.

About 3 miles south-southwest of Walnut, on the farm of John Wright, a hill 50 feet above the stream contains numerous ledges of gray sandstone. At the foot of the hill, in Mr. Wright's yard, the sandstone is soft, resembling the rotten claystone of the Tallahatta buhrstone in Newton County, described on page 29. The ledges near the top of the hill are very hard and contain large casts of fossils. The fossils collected from this locality were referred to Dr. W. H. Dall and were said to be Eocene, but no closer determination was made. The rock is a very coarse-grained sandstone, containing more or less greensand and mica. This sandstone overlies the gray clay referred to above.

The same sandstone occurs on the high hills northeast of Tiplersville, where it is also underlain by gray clay.[a]

From the above data the following section, which shows the relations of the Eocene of Tippah County overlying the Cretaceous, may be given:

*Generalized section of the Midway group in Tippah County.*

| | | Feet. |
|---|---|---|
| Porters Creek: | 6. Gray fossiliferous sandstone capping tops of hills northeast of Tiplersville and southwest of Walnut | 50–75 |
| | 5. Gray, lead-colored, noncalcareous clay, weathering white as seen 1 mile north of Walnut and in the vicinity of Ripley | 50–75 |
| Clayton: | 4. Greenish to gray sandstone, as seen at Chalybeate and in the town of Ripley | ½– 2 |
| | 3. Yellow micaceous sandy marl, in places fossiliferous, seen at Ripley and Chalybeate. | 30–34 |
| | 2. Turritella limestone, seen at Chalybeate and east of Ripley | 5–15 |
| Cretaceous: | 1. "Owl Creek" marl, of Cretaceous age. | |

The same order of Midway strata that is found in Tippah County continues southward through Union and Pontotoc counties, but the exposures are less frequent. Three miles west of Ecru, on the farm of Clay Lemon, is a gray sandstone similar in appearance to that in Tippah County. The hard ledge of limestone outcropping on the west bank of the branch along the Ecru and Oxford road one-half mile west of Ecru is doubtless the limestone of Clayton age, though no fossils were obtained from this locality.

One and three-fourths miles south of the town of Pontotoc, in a deep cut on the line of the new railroad, is a greenish-yellow coarse-grained sand from which a few fossils were collected and referred by Dr. W. H. Dall to the Midway group. Very little work has been done from Pontotoc south to Alabama. In that State the Midway is well developed and has been described in the Coastal Plain report already cited.

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[a] See Geology and Agriculture of Mississippi, 1860, p. 112.

Detailed work in Oktibbeha County by Prof. W. N. Logan, of the Agricultural and Mechanical College of Mississippi, failed to reveal any Midway beds. In Kemper County some time was spent during the present survey along the contact between the Cretaceous and Tertiary, but the Clayton limestone, if present, does not come to the surface.

## WILCOX FORMATION.

This important division of the Tertiary occupies a large area in northern and central Mississippi. It was originally named the Lignitic by Hilgard, and Doctor Safford, State geologist of Tennessee, termed it the Lagrange. A recent decision of the committee on nomenclature of the United States Geological Survey has substituted the name Wilcox, which is that of a locality in Alabama where the formation is typically exposed. The group is made up largely of highly-stratified siliceous sands, laminated clays of various colors, interstratified in places with beds of lignite, and lignitic clays. More or less glauconite or greensand is found throughout the group, and is usually associated with beds containing marine fossils.

In Alabama, Smith has separated the old Lignitic group into six divisions. In each there are one or more marl beds, from which distinguishing fossils are obtained. He includes in the Lignitic the Sucarnochee and Naheola clays, which in Mississippi have been combined under the name Porters Creek and mapped with the Midway.

The four remaining Alabama divisions of the Wilcox can be traced by the fossiliferous marl beds for a short distance into Mississippi, but they apparently fade out, and in the northern part of the State the Wilcox is barren of fossil fauna. It might be added that the fossils mentioned by Hilgard in his Geology and Agriculture of Mississippi, page 112, were later referred to the Middleton formation[a] of Tennessee, or Midway of the present report. There is no single lithologic stratum in the group which can be traced throughout the State except, perhaps, the 150 or 200 feet of chocolate-colored clays immediately underlying the Tallahatta buhrstone. This bed is fairly persistent across Alabama, and occurs at various places in Mississippi. There is also a great thickness of chocolate-colored clays in the deep well at Memphis, Tenn. Certain horizons in other parts of the group are more or less persistent in some localities. Lignite beds may be used as key strata in very limited areas. The white pottery and stoneware clays are well developed in northern Mississippi and represent a fairly definite horizon for this section, but they gradually fade out in the central part of the State.

Lignite is prevalent throughout the entire group, being found in numerous places in the lower, middle, and upper Wilcox. In places it is exceedingly pure, with a black glossy color very much resembling anthracite coal. When dry it burns with a bright-red flame.

No accurate data are available for determining the thickness of the Wilcox. There are no deep wells known to have passed through it, so that the only means left for determining the thickness is by calculating the dip, principally from logs of wells which are supposed to obtain their supply of water from the same horizon in the Wilcox. Estimates of this kind have been made from the records of wells between Oxford and Batesville, between Batesville and Belen, and between Batesville and Riverside. The westward dip was thus found to be 16 feet between Oxford and Batesville, 17 feet between Batesville and Belen, and 18 feet between Batesville and Riverside.

The thickness, therefore, estimated from a westward dip of 17 feet per mile and a width of outcrop of 50 miles, is 850 feet. It is quite possible, however, that the dip flattens toward the west, since the arm of the Gulf at the close of Wilcox time was becoming narrower and the beds more horizontal. It is safe to assume, therefore, that 850 feet is the minimum thickness of the formation in northern Mississippi. L. C. Glenn reports that the deep well at Memphis passed through the Wilcox at a depth of 963 feet.

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[a] Bull. Geol. Soc. America, vol. 3, pp. 511-512.

The character of the Wilcox in its lower portion is well shown in the railroad cut 1½ miles east of Ackerman, Choctaw County. The cut is through the divide between the waters of Tombigbee and Pearl rivers, and the following section is exposed:

*Section of lower Wilcox formation 1½ miles east of Ackerman.*

| | Feet. |
|---|---|
| 11. Lafayette sands and sandstone which has been cemented into a ferruginous mass capping top of ridge. In places this sandstone is 10 to 15 feet thick | 20 |
| 10. Yellow stratified sand | 10 |
| 9. Bed of lignite which is not continuous, but changes laterally into a dark lignitic clay. When wet the whole mass has a tendency to slide down on the railroad track. Large pilings have been driven into the earth to prevent landslides. There is more or less sand and mica throughout the whole mass of lignite and lignitic clay | 5 |
| 8. Dark-blue clay, weathering to gray | 6½ |
| 7. Impure lignite | 1 |
| 6. Chocolate-colored joint clay | 5 |
| 5. Thin band of ferruginous sandstone | ½ |
| 4. Dark-blue clay, similar to No. 8 | 4½ |
| 3. Laminated dark clay | 6 |
| 2. Laminated clay in which thin ferruginous bands alternate with bands of soft chocolate clay | 5 |
| 1. Gray micaceous joint clay, weathering to white; bottom of cut | 5 |

The strata have a slight dip to the west. The above section shows that the prevailing material here is clay, with a slight amount of sand through the clay.

One mile north of Ackerman a section in the deep cut along the newly constructed Mobile, Jackson and Kansas City Railroad shows less clay and more sand.

*Section of Wilcox formation 1 mile north of Ackerman.*

| | Feet. |
|---|---|
| 3. Lafayette sand | 2 |
| 2. Cross-bedded sandy gray clays, alternating with bands of yellow clayey sand | 15 |
| 1. Dark-gray sandy clays, containing fragments of leaves and lignitic material | 10 |

At the north end of the cut the clayey material is replaced at the same level by a mass of coarse-grained siliceous sand of gray, yellowish, and purple colors.

Along the Mobile, Jackson and Kansas City Railroad, in the vicinity of Maben, there are numerous cuts which show a dark-blue, highly micaceous, plastic clay containing small lenses of sand. Many of the wells reach this blue clay, which produces a bad water. The clay in places is so compact that the wells do not have to be curbed. The same variation of sands and clays is found along the eastern border of the Wilcox.

Hilgard [a] gives the following section near Hickory Flat, in sec. 33, T. 5 S., R. 1 E.:

> There is a bluff about 70 feet high, which consists of alternating strata, from one-fourth inch to 2 feet in thickness, of gray and brown clay, sand, and sandy clay; the whole overlaid by a few feet of Orange sand [Lafayette].

The following section is also taken from the same source, page 114:

*Section of lignite strata, from an outcrop in T. 6 S., R. 1 E.*

| | Feet. |
|---|---|
| 3. Gray sandy clay with conchoidal cleavage, nonfossiliferous | 6 |
| 2. Black laminated clay with impressions of leaves and a seam of lignite at the base | 1½ |
| 1. Blue massy clay, nonfossiliferous | 8 |

> This section represents faithfully numerous outcrops in southern Lafayette and northern Calhoun counties. Some sections, however, exhibit nothing but sharp, yellow sand, with faint impressions of leaves. The region in which the above section occurs is remarkable for the number and large size of the ferruginous nodules occurring on the surface of the formation; silicified trunks, also being very common in the same position, and remarkable for the perfect preservation of their vegetable structure.

Farther west, near the center of the formation, there appears a greater amount of purer stoneware clay and less of the dark-blue lignitic clays. This is particularly true in Marshall and Lafayette counties, south of which the white stoneware clays seem to grade into the more lignitized darker clays. The same line of clays continues north from Marshall

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[a] Geology and Agriculture of Mississippi, 1860, p. 112.

County into Tennessee, and their outcrop through Tennessee and Mississippi is marked by a line of stoneware and jug factories.

The purer white stoneware clays usually occur in large lenses in the coarse variegated sands below the Lafayette. In some places these lenses occur far below the Lafayette, entirely in the Wilcox sand. In others there is no Wilcox sand above the clay, so that the Lafayette rests directly on it. For this reason the clay was thought by W J McGee [a] to belong to the Lafayette formation. The clay lenses have never been found, however, entirely in the Lafayette, but they have been found many feet below the Lafayette entirely in the laminated sands of the Wilcox.

Numerous specimens of fossil leaves are found in the clays used at the potteries at Holly Springs and throughout Tennessee. Species of fossil plants collected near Somerville, Fayette County, Tenn., by Prof. J. M. Safford, were determined by Leo Lesquereux. The age of the strata in which these fossils were found was said by Lesquereux to be lower or middle Miocene. A study of the Tertiary in central and eastern Mississippi and Alabama makes it impossible to place the Wilcox in the Miocene. It has been proved by Hilgard, Smith, and others that the Jackson, which represents the highest division of the Eocene, is much younger than the youngest member of the Wilcox. Not only this, but there are two formations—the Tallahatta buhrstone and Lisbon beds of the Claiborne—intervening between the upper Wilcox and lower Jackson.

At Redbanks, on the Frisco Railroad, Marshall County, is a high ridge, the waters on the north side flowing to Chewalla Creek and those on the south side to Redbank Creek. Erosion along this ridge has been very rapid in places, removing the surficial clays and loam of the Lafayette and the yellow loam or Columbia and exposing the white stoneware clays in the stratified Wilcox sands. In places erosion has been so extensive that the lenticular character of the stoneware clays is easily determined. The material surrounding the clay lenses is a coarse, variegated sand, highly cross-bedded. Where not removed by erosion the Lafayette and Columbia overlie the Wilcox.

In sec. 25, T. 3, R. 3 W., the following succession of strata is found, showing the relation of the sands to a more siliceous nonplastic clay, which appears in lenticular shape 100 yards long and 10 feet thick:

*Section of Wilcox formation in sec. 25, T. 3 S., R. 3 W.*

| | Feet. |
|---|---|
| 4. Yellow loam | 8 |
| 3. Lafayette | 2½ |
| 2. Irregularly bedded white and yellow sands | 10 |
| 1. Red, coarse-grained sand containing layers of ferruginous sandstone; bottom of exposure. In this sand the white clay occurs. | |

Along the same line to the south, particularly in Lafayette County, there is a greater amount of impure, siliceous, and highly stratified clay, which from a distance often has the appearance of white chalk banks. There is likewise a less amount of clay occurring in lenticular masses. Good workable clay often occurs in horizontally bedded strata.

The following section, from a deep gully near Sid. Wyley's house, in sec. 16, T. 8 S., R. 4 W., is typical for this locality:

*Section of Wilcox formation in sec. 16, T. 8 S., R. 4 W.*

| | Feet. |
|---|---|
| 5. Yellow loam and Lafayette at surface. | |
| 4. Impure yellow clay | 2 |
| 3. White stoneware clay, horizontally bedded | 10 |
| 2. Siliceous ferruginous clay | 1½ |
| 1. Gray and white sand to bottom of gully | 2 |

Lignite occurs to a greater or less extent throughout the entire Wilcox group, but it is more abundant and purer at certain localities than at others. It seems to be confined to local basins rather than to form continuous strata at certain horizons. It is always associated with lignitic clays bearing lignitized wood, leaves, and bark.

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[a] The Lafayette formation: Twelfth Ann. Rept. U. S. Geol. Survey, pt. 1, 1891, p. 458.

The lignite in a compact, pure state is impervious to water and gives rise to numerous springs where it comes to the surface. The descending waters carry more or less iron oxide in solution, and when the water is checked by the lignite bed the iron is precipitated, forming a thin roof on top of the lignite. It is often underlain and overlain by pure refractory clay, and where there is such an overlying bed the iron-charged waters are checked before reaching the lignite.

The largest area where lignite has been found is in southeastern Lafayette and northwestern Calhoun counties. It occurs here in workable veins, reaching a maximum thickness of 6 feet.

A bed 28 inches thick occurs on A. D. Lancaster's place, in sec. 33, T. 9 S., R. 2 W. It outcrops in a deep ravine about 50 feet above Yocona Creek. Immediately above the lignite is a brown clayey micaceous sand, 10 inches thick, teeming with fossil leaves resembling oak and a narrow lanceolate leaf or reed. A very compact black lignite, 5 feet thick, outcrops at the foot of a high hill on J. A. Head's land, in sec. 11, T. 11 S., R. 2 W. A second seam is reported to have been struck 15 feet below the upper layer. The lower bed is thinner than the upper and contains more iron pyrite. The upper bed marks the outcrop of numerous bold springs over a large area in this vicinity. A well at Paris, in sec. 32, T. 10 S., R. 2 W., is reported to have passed through 18 feet of surface clay and sand, 6 feet of lignite, and 3 feet of greensand in which a stream of water was found. More or less lignite occurs along the bluff skirting the Yazoo delta in Panola and Yalobusha counties. Here it is associated with the dark-brown clays at the top of the Wilcox.

A sample of lignite was collected from a bed near De Kalb, Kemper County. Hilgard and others report lignite from near Marion, Lauderdale County, and from localities in Choctaw, Yalobusha, and Tippah counties.

In the upper portion of the Wilcox there are 200 to 250 feet of dark-brown or chocolate-colored clay. It is highly laminated and often cross-bedded. In places it contains more or less greensand and often variegated siliceous sands. The surface outcrop is most characteristically developed on hillsides along Yalobusha River in Grenada County, and it is found in wells in the same area. The hills in the vicinity of Grenada expose from 100 to 150 feet of the Wilcox clays. Near the top of the hills the clay is often of a light-gray to bluish color, becoming darker near the base. More or less green, yellow, and gray sand is found alternating with the lighter colored clays. The darker clays in the river bank contain but little sand.

The following section is from the hill just west of Grenada:

*Section of Wilcox formation west of Grenada.*

| | Feet. |
|---|---|
| 4. Yellow loam and Lafayette capping top of hill. | |
| 3. Impure laminated gray clay | 50 |
| 2. Greensands interbedded with thin layers of clay | 50 |
| 1. Darker colored laminated clays, the lower 15 feet being the dark-blue, highly cross-bedded, shaly clay seen in the bank of the river. It is almost entirely free from sand | 50 |

Four miles west of Grenada the hard quartzite of the Tallahatta buhrstone occurs near the crest of the hills. How much, therefore, of these clays, if any, belongs to the Claiborne has not been determined.

Still farther north, along the western edge of the Wilcox hills in Panola County, the same brown clays occur associated with more or less lignite. They can be traced in the wells and outcrops along the western edge of the Wilcox to Memphis, where 250 feet or more of dark, compact "soapstone" or clay is reported.

### CLAIBORNE GROUP.

The Claiborne is divisible on lithologic grounds into two distinct formations; the lower of these is the Tallahatta buhrstone or "siliceous Claiborne," and the upper includes the Lisbon beds or "calcareous Claiborne."

### TALLAHATTA BUHRSTONE.

The Tallahatta buhrstone, called the siliceous Claiborne by Hilgard, outcrops in a belt of territory between the Wilcox and the Lisbon beds or calcareous Claiborne. This belt varies in width from 10 miles in northeastern Clarke County to about 30 miles in Holmes, Carroll, and Montgomery counties.

In lithologic character the Tallahatta buhrstone stands out in sharp contrast to the soft, unconsolidated sands, clays, and lignites of the Wilcox, and likewise to the more marine deposits of calcareous clays and fossiliferous marls which were laid down immediately after the deposition of the buhrstone. The principal rocks of this formation consist of the following:

1. Aluminous sandstone of a prevailing gray to white color and often containing a large amount of oxide of iron. More or less fossils, principally casts, have been found in this rock in both Mississippi and Alabama.

2. Next in order of abundance is the siliceous and aluminous clay stone. This rock is found in numerous places near the Alabama border in Clarke and Lauderdale counties, but north of this the harder sandstones are the prevailing materials.

3. Quartzitic sandstone or "Feldsen mur." This is the rock which has given the name to the whole series. It is an exceedingly hard sandstone which, by metamorphism, has lost much of its original sandy character. Some of the specimens collected show the sandstone in the process of change from the coarse-grained sand to the hard quartzite. The quartzite is usually found in layers ranging from 2 to 3 feet thick. When long exposed to eroding agents it is found strewn along the hillsides in large, flat bowlders. Smith [a] considers the quartzite to be the basal member of the Tallahatta buhrstone formation. This is overlain by aluminous clay stone which is flecked with small fragments of clay or "gallstones." This clay rock is very light gray to white in color, containing two sets of joints approximately at right angles to each other. In places, as at Basic, in northern Clarke County, these joints have been filled with sand and other materials forming small dikes, and the whole cemented together with iron oxide. The intruded material is more resistant than the indurated clay stone and gives rise to unequal weathering.

4. Greensand and marls. These are found in less abundance than any of the other materials. However, more or less greensand grains occur throughout the siliceous sandstone of the formation.

An interesting section at Vaiden is given by Hilgard: [b]

> In the middle of the cut the coarse, glauconitic, dark orange-colored, ferruginous sandstone forms a pretty uniform stratum about 3 feet thick; it is in this that the fossils are most abundant. These are preserved as impressions and nuclei only. Underlying this rock and in the cut adjoining northward alternating with it there occurs a stiff amorphous clay with sharp sand and some greensand grains, also of deep orange tint and exhibiting traces of fossils.

On the south side of Kirkwood Ferry, about sec. 11, T. 16 N., R. 5 E., is a bluff about 70 feet high showing the Tallahatta buhrstone, of which Hilgard [c] gives the following section:

*Section of Tertiary strata at Kirkwood Ferry.*

| | Feet. |
|---|---|
| 6. White siliceous sandstone; nonfossiliferous | 1 |
| 5. Yellow sand, grains rounded; no fossils (orange sand) | 3 |
| 4. Dark orange-colored glauconitic sandstone; fossils as at Vaiden | 2 |
| 3 Ferruginous sand, somewhat glauconitic, with few fossils | 20 |
| 2. Gray laminated clay | ½ |
| 1. Yellow sand, without fossils | 20 |

No accurate measurement of the thickness of the Tallahatta buhrstone has been made in Mississippi. The city waterworks at Kosciusko struck a bed of fossiliferous marl at a depth of 65 feet. This marl bed is immediately overlain by a stratum of hard "flint rock" 34 inches thick, and is underlain by a stratum of softer rock.

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[a] Coastal Plain of Alabama, p. 140.

[b] Geology and Agriculture of Mississippi, 1860, p. 121.

[c] Op. cit., p. 122.

At a depth of 150 feet a second bed of fossiliferous marl was found which contained fewer fossils and more greensand than the upper bed. A sufficient number of fossils were not kept from this well to determine the exact horizon of the two beds. On Yokahockany River just south of Kosciusko the quartzitic sandstone outcrops along the road near the bridge. This is doubtless the same horizon as the "flint rock" 65 feet below the surface in the Kosciusko well. Considering the "flint rock" as the base of the Claiborne and the upper marl bed as the uppermost fossiliferous bed of the Wilcox, we then have 65 feet of Tallahatta buhrstone in the well. The elevation of the top of the well is about 15 feet above the railroad track at Kosciusko, or 437 feet above sea level. The hills, which are capped by the Tallahatta buhrstone 5 miles north of Kosciusko, rise to an elevation of about 600 feet, barometric reading. Considering the rocks horizontal, we have a thickness of 220 feet for the entire formation.

Smith has estimated the thickness of the Tallahatta buhrstone in Alabama to be at least 300 feet. A less thickness should be expected in central Mississippi than in Alabama, since the width of the outcrop becomes less to the north and the formation has not been found to cap even the highest hills north of Yalobusha River in Grenada County.

This formation offers a strong contrast, in both topography and character of materials, to the adjacent older and younger formations. The hills of the Tallahatta buhrstone are high and, where capped by the harder portions of the sandstone and quartzite, are very precipitous and rugged. In northwestern Neshoba and northeastern Leake counties Pearl River and some of its tributaries have cut out deep ravines in the sandstone, giving rise to wild and picturesque scenery. Short-leaf pine is the principal timber on the hills, with oak, hackberry, gum, and hickory along the creek bottoms. The soil is thin and has a deep, Indian-red and often blood-red color. The decomposition of the sandstone, which contains a large amount of iron oxide, gives the striking red color to the soil. It is easily distinguished from the orange-colored soil of the Lafayette and from the chocolate and gray soils of the Wilcox and Lisbon formations. The region is very sparsely populated and undeveloped, owing to the poor quality of soil and the readiness with which it "wears out" and washes away.

The old shore line at the beginning of the deposition of the Tallahatta buhrstone is traceable from the Alabama line, 4 miles south of Hurricane Creek post-office, in a general northwest direction past Eastville to a short distance southwest of Philadelphia, then bearing a little more to the north through Plattsburg and Hinge, 4 miles west of McCool, through French Camp and Minerva to a point 4 miles west of Grenada, where the formation dies out.

The principal variation from a direct line of outcrop extending from the Alabama border to the locality 4 miles west of Grenada is due to the irregularity of the surface configuration.

The geologic map of the State (Pl. I) shows that the formations older than the Tallahatta buhrstone, after swinging into Mississippi from Alabama, begin to assume a more nearly north-south direction. The buhrstone trends from northwest to southeast, while the younger Lisbon, Jackson, and Vicksburg gradually take an east-west direction. This is due to a more rapid filling in the northern part of the embayment about the close of the Wilcox period. The broad embayment which at first extended from northern Alabama across the present State of Mississippi and eastern Arkansas had, at the beginning of Claiborne time, become reduced to a comparatively narrow arm of the sea, which still extended north as far as southern Illinois. The great amount of sediment which was being carried into the embayment from the east, north, and west gradually filled in and finally closed the narrow inlet. Before it was entirely closed there was a gradual lessening of the dip of the sea floor on which the material was being deposited. The last formation to be deposited was, therefore, almost horizontal, with a slight dip to the deeper sea. In recent investigations along Crowley Ridge, in northeastern Arkansas, the formations were found to have a very slight dip to the south.

A good opportunity for investigating the upper division of the Tallahatta buhrstone is given along Okatibee Creek between Basic and Enterprise. About 2 miles southwest of Basic and 2 miles northeast of Enterprise, where the New Orleans and Northeastern Railroad comes nearest to Okatibee Creek, the aluminous clay stone of the upper part of the buhrstone disappears beneath the fossiliferous beds of the overlying Lisbon beds.

At Basic station the principal part of the deep railroad cut is in the aluminous clay stone, which occurs in solid ledges 2 to 6 feet thick. When dry it is very light, and from a distance may be taken for white chalk The top of the hill, above the cut, is covered with large bowlders of hard, yellow sandstone with flint-like nodules through it.

Doctor Hilgard mentions the presence of a yellow aluminous sandstone in southern Neshoba County. The rock, he says, "is very poor in fossils at its northern edge, but becomes richer as we advance southward."

In the bed of Chunkey Creek, near Chunkey station, the aluminous clay stone forms high, perpendicular walls. Here, as at Basic, joints through the rock are well developed.

On Thomas Tillman's land, in sec. 9, T. 7 N., R. 11 E., the more siliceous sandstone of the Tallahatta buhrstone comes to the surface. It is highly colored with rusty and pink streaks of iron oxide. After long exposure it becomes soft and easily broken. It occurs in thin layers, 3 to 8 inches thick, interbedded with an indurated clay. The stone here is quarried and used locally for foundation pillars, chimneys, and hearthstones. It withstands a large amount of heat without cracking and is therefore known as the "fire rock."

Still farther north, between Philadelphia and Edinburg, are numerous outcrops of the soft iron-stained sandstone. A hill on the south side of the road one-half mile west of Worth post-office, in sec. 25, T. 11 N., R. 10 E., Neshoba County, rises about 75 feet above the bed of the creek. Near its crest is a ledge of sandstone from which large bowlders have broken loose and rolled down the hillside, almost completely covering it.

In western Neshoba and eastern Leake counties the typical "red lands" of the Tallahatta buhrstone are well developed. The decomposition of the sandstone rock forms a deep-red clay loam. It was at first confused with the Lafayette, but the red clay loam is always free from pebbles and ferruginous conglomerate.

In the bed of Pearl River at Edinburg there is a soft aluminous micaceous sandstone containing small angular fragments of flint or chert. The presence of iron oxide in the rock gives it a highly mottled appearance. The rock occurs in thin layers 8 to 10 inches thick interbedded with micaceous, indurated siliceous clay. The pillars for the bridge across Pearl River are said to have come from the bank of the river just below the bridge.

Two and one-half miles northeast of Edinburg, on Mr. Unsel's land, a very hard quartzose sandstone, much harder than any found farther south, occurs on the crests and sides of the hills and is used locally for building stone. The fine pillars under many of the buildings in Edinburg are said to have come from the Unsel place.

The hills in northwestern Neshoba, northeastern Leake, and southeastern Attala counties, where not covered with Lafayette and detritus, show the presence of the Tallahatta buhrstone. In some places it is very soft and white; in others it is more flint-like and often contains casts of fossils.

Along the eastern edge of the buhrstone area in the vicinity of Alice there is apparently more greensand near the base of the formation than higher up. The greensand is mixed with yellow clays, and below it is a grayish to dark-brown clay containing free sand.

Along the road between Kosciusko and Edinburg, in sec. 15 (?), T. 13 N., R. 8 W., is a bed of marl mixed with greensand underlying a thin stratum of ferruginous sandstone. The marl bed teems with fossils, but unfortunately the species collected from this place were not sufficient to determine whether it is Claiborne or upper Wilcox.

Five miles north of Kosciusko the main body of the quartzitic sandstone occurs. On J. C. Bell's land there are two sandstone ledges separated by 20 to 25 feet of clayey sand. The upper ledge is 10 to 12 feet thick; the lower one is partly covered by detritus, but is perhaps 15 feet thick. When freshly dug from the hillside the sandstone is white, fine grained, and highly siliceous, with pink streaks through it. Some of the ledges farther down the slope have lost their original sandy character and are now almost a pure quartzite. The best steel hammer is easily battered by striking it against this rock.

In the railroad cut at Hoffman, Holmes County (Pl. IV, *B*), the following section of the Tallahatta buhrstone was obtained:

*Section of Tallahatta buhrstone at Hoffman.*

| | Ft. | In. |
|---|---|---|
| 8. Yellow loam, with Lafayette wanting | 7 | |
| 7. Hard quartzitic sandstone, gray with bluish tints | 2 | 2 |
| 6. Compact, stratified sand, with brownish and yellowish tints | 3 | 6 |
| 5. Ledge of white stratified sandstone, not so hard as No. 7 | 3 | 6 |
| 4. Chocolate-colored clay, highly micaceous | 3 | |
| 3. Ledge of indurated chocolate-colored clay | 1<br>to 1 | <br>2 |
| 2. Earthy lignite, passing into No. 1 | 1 | |
| 1. Chocolate-colored clayey sand, highly micaceous, containing small iron concretions; bottom of cut | 6 | |

The Tallahatta buhrstone comes to the surface in the hills on the west side of the creek which empties into Yokahockany River at Ethel, in eastern Attala County. The principal outcrops occur in secs. 33, 30, 29, 28, and 21, T. 15 N., R. 8 E. In each of these places the rock is a gray, soft, micaceous sandstone, containing more or less iron oxide. It is found well up on the hillsides 30 to 40 feet above the stream. Its relation to the underlying and overlying strata is not known, owing to the large amount of detritus on the hillsides. However, as this is the easternmost outcrop known in this latitude, the sandstone must represent something like the base of the formation. The elevation of Ethel is 435 feet above sea level.

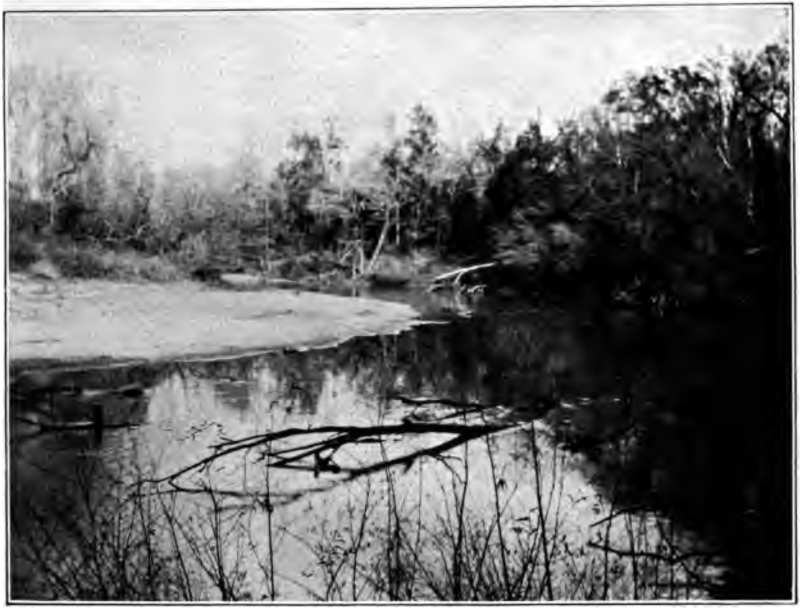
The Ethel and Kosciusko sections offer an opportunity for determining the dip of the formation. The hard quartzitic layer just above the fossiliferous marl bed in the well at Kosciusko has been considered above (p. 29) to be the base of the Tallahatta buhrstone. The altitude of this quartzitic horizon is 380 feet above tide. Considering the base of the formation to come to the surface near Ethel at an altitude of 475 feet, and the distance between Ethel and Kosciusko to be 9 miles, we thus get a southwesterly dip of 10 5/9 feet to the mile.

A comparison based on railroad elevations of the Hoffman and Kosciusko sections leads inevitably to one of two conclusions—(1) that the fossiliferous marl bed 65 feet beneath the surface in the Kosciusko well is not Wilcox, but a part of the Tallahatta buhrstone, or (2) that there is considerable warping of the strata which has never been taken into consideration.

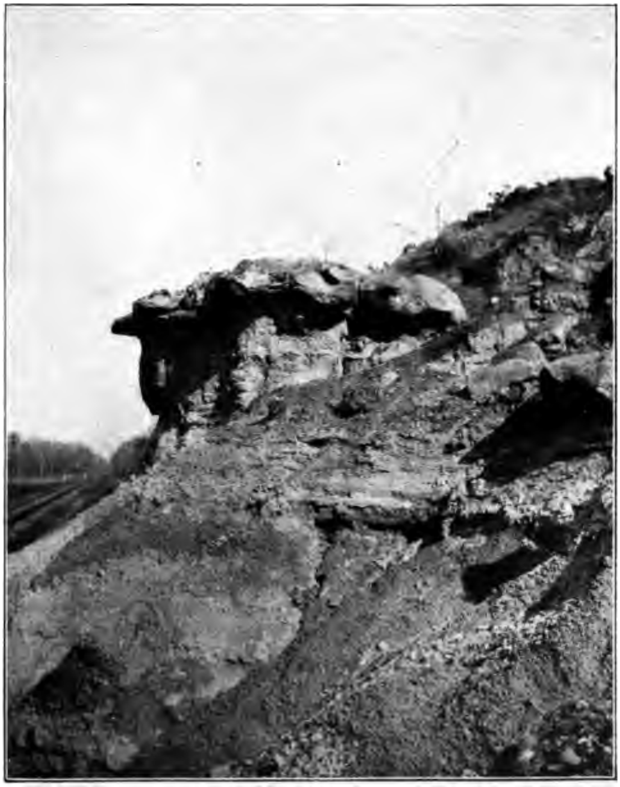
The elevation of the marl bed in the Kosciusko well is approximately 380 feet above tide. At Hoffman, 12 miles west of Kosciusko, what has been considered the base of the formation outcrops in the railroad cut at an elevation of 293 feet above tide, or 87 feet lower than the buhrstone bed at Kosciusko. If the quartzite at Hoffman were at the base of the Tallahatta buhrstone, there would be a strong dip of 7¼ feet per mile to the west. But the buhrstone outcrops at Ethel, 9 miles east-northeast of Kosciusko, and again 6 miles east of Winona. It is therefore impossible to get the base of the formation at Hoffman unless there is a strong folding of the strata in this region. Such folding has never been detected by anyone, and we are thus forced to the conclusion that the fossiliferous marl bed in the Kosciusko well is in the Tallahatta buhrstone and that the formation is much thicker than estimated above (p. 30), or else the quartzitic ledge is not the base of the formation.

In the hills 6 miles east of Winona a gray sandstone occurs having the same character as that found near Kosciusko, Hoffman, and other places farther south, showing both the hard quartzitic layer and the softer aluminous sandstone containing mica and highly colored with iron oxides.

The northernmost place in Mississippi where the Tallahatta buhrstone has been found is on the poorhouse farm 4 miles west of Grenada, Grenada County. Here the blue to pink-tinted quartzite occurs in large, rough bowlders on the highest hills. If the old shore line representing the eastern edge of the Tallahatta buhrstone continued its northwest course north of Yalobusha River, as it does from the Alabama line to Grenada, the Claiborne north of this point has been removed by the same agency which carved out the Yazoo bottom.



*A*. BED OF GLASS SAND ON PEARL RIVER NEAR BYRAM.



*B*. LEDGE OF TALLAHATTA QUARTZITE, HOFFMAN.

### LISBON BEDS.

The uppermost division of the Claiborne is a series of clays and sands, which Hilgard called "calcareous Claiborne." The formation is estimated to be 150 feet thick in Alabama, where it is composed of calcareous sands and laminated and lignitic clays. There is one horizon in Alabama in which a distinguishing fauna occurs. This is a bed of yellowish ferruginous sand 15 to 17 feet thick, containing numerous species of beautifully preserved Claiborne fossils. A large number of the fossils in the Lisbon beds range through the overlying Jackson and Vicksburg formations.

The fossiliferous horizon above mentioned has been described by Hilgard as occurring on Falling Creek, near Quitman, Clarke County, Miss., and on Suanlovey Creek, west of Enterprise. L. C. Johnson has also collected fossils from the same bed at the Wautubbee cut, southwest of Enterprise. Here it is 17 feet thick and is the best collecting bed of the Claiborne so far found in Mississippi.

The same bed outcrops again 4 miles northwest of Newton, in Newton County. The material in which the fossils occur is a blue calcareous sandy marl. The bed here is much thinner than at Wautubbee. Frank Burns, of the Smithsonian Institution, has made a large collection of fossils from this place, as well as from numerous other places west of Hickory and along the road between Hickory and Quitman. The fossils have all been examined by Dr. W. H. Dall and referred by him to the Lisbon beds of the Claiborne. Near Hickory and southward to Quitman most of the fossils occur in a sandy "soapstone" or clay.

One mile south of Enterprise, on Chickasawhay River, is a bed of *Scutella lyelli*, which has become cemented into a hard rock, as reported by Mr. Burns. The Scutella bed overlies a bed of fine ash-colored marl, which contains a large amount of greensand, but is devoid of fossils at this place.

In the railroad cut 1½ miles west of Decatur Claiborne fossils occur in a bed of dark-blue glauconitic clay marl. This is doubtless near the base of the formation, as the buhrstone outcrops about 4 miles northwest of Decatur.

### JACKSON FORMATION.

In Alabama the Jackson and the succeeding formation, the Vicksburg, have been classed together under the name of St. Stephens. In Mississippi, however, the two formations can usually be separated quite readily and will be treated as two distinct formations.

The essential materials of the Jackson group are gray calcareous clay marls and bluish lignitic clays, with greensand and gray siliceous sands. From a lithologic standpoint there is very little difference between the calcareous clays and marls of the upper Claiborne and those of the lower Jackson. In general the color of the clays becomes lighter in the Jackson, with possibly a less amount of lignitic material. So far, however, the principal reason for keeping the two formations separate is based on paleontologic evidence. In some localities where fossils have been collected, the so-called Claiborne fossils were so evenly distributed with those of Jackson age that it has been difficult to say in which formation the beds belong. There is need of a more comprehensive study of the stratigraphy in connection with the fossils in order to draw the line between the two formations correctly. This line as mapped in Mississippi is, therefore, only approximately correct. The upper ferruginous sandy marl containing Claiborne fossils has been seen in but few places in the State. Smith,[a] in speaking of the distinction of Claiborne and Jackson rocks, says:

> The rocks of the Claiborne group are distinguished from those of the white limestone (Jackson and Vicksburg of Mississippi) by the presence of glauconite in large proportion, and this Scutella bed is the first of the ferruginous beds of the Tertiary. We are undecided whether this Scutella bed should go with the white limestone or with the Claiborne, since the fossil is found in both formations.

Only a few feet below this Scutella bed are the Claiborne fossiliferous sands, so that even where the formations have been best studied there seems to be a gradation in both the fossils and stratigraphy from the upper Claiborne to the lower Jackson. Many of the forms found in the Claiborne are found throughout the Jackson and the succeeding formation, the Vicksburg.

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[a] Coastal Plain of Alabama, p. 111.

Conrad[a] described a large number of fossils from the vicinity of Jackson, and was the first one to give that name to the formation.

> He assigned [says Dall[b]] to the strata their proper stratigraphical position above the Claiborne and below the Vicksburg, although from the nature of the material he had for examination he failed to recognize the true faunal relationship of the several horizons. His investigations led him to the conclusion that there were no forms in common with the Vicksburg series, and but four or five with the Claiborne. Subsequent observations, however, have shown in Mississippi, as well as in Alabama, that there are many forms common to the three horizons. Such common species as *Cardita planicosta* and *Cardita rotunda* of the Claiborne, with many less usual types, are found, while the list of species reported as likewise occurring in the Vicksburg is very large.

There is one distinguishing fossil, the *Basilosaurus* (*Zeuglodon*), which has been found only in the Jackson marls. It is usually found on the prairies where the streams have removed the surface soils. These bold prairies, somewhat similar to those found in northeastern Mississippi, are of common occurrence over the Jackson area and serve to distinguish the Jackson from the Claiborne.

Hilgard,[c] in his study of the formation around Jackson, observed what he considered a northern dip of the Jackson beds. He says:

> According to the levelings of the N. O., J. and G. N. R. R., the city of Jackson is situated 45 feet higher than Canton, Madison County,[d] which is distant 25 miles due north from the former place. . . . At Canton we find the highest strata, apparently, of the Jackson group—the gray calcareous clay matrix of the *Zeuglodon*—occupying the surface, though at a moderate depth (20 to 30 feet) the lignito-gypseous material is struck, yielding undrinkable water. The same strata are seen all the way between Canton and Jackson, and crop out very characteristically half a mile north of the statehouse. Yet we find lignitic strata cropping out on Moodys Branch, a mile northeast of the statehouse, and that at a hypsometrical level obviously higher than that at which, a mile below, we find the beds of blue fossiliferous sand cropping out on Pearl River and in the bed of Dry Creek. Making due allowance for the undulations of the surface at both stations (Canton and Jackson), the surface of the lignitic strata, so far from exhibiting a southward dip, is still slightly higher at Jackson than at Canton. It seems difficult to account for this condition of things unless by supposing a local upheaval of the underlying formation to have taken place before the deposition of the lowest of the Jackson stage.

Doctor Hilgard's theory of a northern dip of the strata in the vicinity of Jackson is further substantiated by the occurrence of outliers of the Vicksburg limestone west of Madison. These outliers occur on the hills along the watersheds of Pearl and Big Black rivers, but if the southern dip of the Vicksburg, as observed along Pearl River at Byram, continued northward the Vicksburg would not touch the tops of even the highest hills, as the following elevations will show. The elevation of the lowest member of the Vicksburg limestone on Pearl River, 3 miles above Byram, is about 255 feet above tide. Byram, on the bank of Pearl River, is 264 feet above tide. The United States Geological Survey bench mark in sec. 3, T. 7 N., R. 1 E., is 415 feet above tide. This is 1 mile from the northernmost outcrop of the Vicksburg outlier in sec. 10, T. 7 N., R. 1 E., west of Madison, where the elevation of the lowest member is 400 feet above tide, barometric reading. The distance between the northernmost outlier and the outcrop on Pearl River above Byram is 20 miles and the difference in elevation is 145 feet. The southward dip would, therefore, be 7½ feet to the mile.

The dip thus obtained is much smaller than that noticed along Pearl River between Jackson and Byram. D. W. Langdon,[e] who studied the strata along this part of the river, says:

> Six miles above Byram the strata show a dip of about 20 feet in a hundred toward the south. . . . Still farther south the strata dip southward very rapidly, as much as 5 feet in a hundred.

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[a] Proc. Philadelphia Acad. Nat. Sci., vol. 7, 1855, pp. 257-263.

[b] Correlation papers—Eocene: Bull. U. S. Geol. Survey No. 83, 1891, p. 68.

[c] Geology and Agriculture of Mississippi, 1860, p. 128.

[d] According to Gannett, Jackson is 67 feet higher than Canton.

[e] Am. Jour. Sci., 3d ser., vol. 31, pp. 202-209.

The dip to the west was estimated by Mr. Langdon to be 6 to 7 feet per mile.

From the above it seems that there is a great irregularity in the dip of the Jackson formation. From Jackson southward the dip to the south is very great, but farther north it gradually flattens, and probably becomes a slight dip to the north. The irregularities in the dip of the strata in Mississippi may be due to the same cause as that which in Alabama produced the lower Peach Tree anticline, Hatchetigbee anticline, and Bethel fault.[a]

The stratigraphic position of the Jackson is between the Claiborne and Vicksburg, as pointed out by Conrad, Hilgard, Smith, and others. Its area is more extensive than that of either the Claiborne or Vicksburg, occupying a stretch of country which is narrowest in the east and gradually widens to the west. The increasing width to the west is explained by the fact that in the east the dip to the south is much greater than in the west, where the country becomes more level and the dip in some places almost horizontal.

The Jackson area can usually be traced across the country by the rich calcareous prairie soils. Owing to the absence of deep-well records over the area, it has been impossible to determine the thickness of the formation. Estimates have been made from the width of the outcrop, but the irregularities in the dip of the strata in the vicinity of Jackson have rendered the results unreliable.

In Alabama the thickness of the St. Stephen, which includes the Vicksburg and Jackson, is estimated at 350 feet. The Vicksburg in Mississippi is less than 110 feet thick, so that if the combined thicknesses in Mississippi are the same as in Alabama we have 240 feet for the Jackson. It is doubtless much thicker, however. The bluff at Yazoo City shows 180 feet of Jackson clays in one continuous section, and the formation outcrops along the bluff for 12 miles to the north and about 30 miles to the south. With a thickness of 180 feet at Yazoo City, near the northern limit of the area, and with a very slight southward dip, it is more than probable that the entire thickness is at least 350 or 450 feet.

The type locality of this formation, as above mentioned, is at the city of Jackson. This has been the classic collecting ground for the paleontologist, and hundreds of specimens have been found here. The beds in which the well-preserved fossils occur are found at the wagon bridge across Pearl River, on Town Creek, near its mouth, and along a deep ravine about 1 mile north of the old capitol. At none of these localities are the strata horizontally bedded, nor do they preserve their lithologic unity so that any one bed can be traced for any great distance. The gray or greenish marl, replete with fossils, may in 100 feet change to a black lignitiferous clay. Jackson fossils have also been collected at Moodys Branch and McNutt Hill.

The high bluff skirting the east rim of the Yazoo bottom is in most places very steep. The top of the bluff is covered with a much younger formation, the loess, which will be described later (see pp. 48–49). Underneath this loess capping the Jackson may be seen for a distance of about 35 to 40 miles south of Free Run, in northern Yazoo County. Many of the streams have cut through the loess and have exposed the Jackson for some distance back from the western edge of the bluff. At Yazoo City and for several miles north and south this bluff affords excellent sections of a gray to bluish clay marl bearing a typical Jackson fauna. The height of the bluff above the river is 280 feet. The lower 180 feet are composed of gray calcareous clay containing crystals of gypsum, *Zeuglodon* bones, and other Jackson fauna. Above this are 10 to 12 feet of Lafayette sands and gravel, and this in turn is overlain by about 100 feet of loess.

The "bald prairies," underlain by the gray calcareous clays bearing the bones of *Zeuglodon*, can be traced across the counties of Madison, Scott, northern Smith, Jasper, southern Clarke, and northern Wayne, into Alabama.

The country along Chickasawhay River and some of its tributaries affords better opportunity for collecting Jackson fossils than the central part of the area. Along the Chickasawhay, in sec. 21, T. 1 N., R. 16 E., Clarke County, is a bluff 30 feet high of calcareous clays, from which Hilgard[b] collected many Jackson fossils. He mentions, among other localities from which he collected Jackson fossils in Clarke and Wayne counties, Trotter's plantation, in sec. 3, T. 10 N., R. 7 W.

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[a] Coastal Plain of Alabama, pp. 207-211.

[b] Geology and Agriculture of Mississippi, 1860, p. 134.

The Jackson has usually been described as being entirely made up of marls and clays, but recent investigations along the line of contact between the Jackson and Vicksburg have shown that there are from 50 to 75 feet of yellow, gray, or white siliceous unconsolidated sand at the top of the Jackson. Whether from a paleontologic standpoint this should be considered Jackson or Vicksburg is doubtful, since no fossils have been found in these sands. They are regularly stratified, showing that they were deposited very near the old shore, in more or less current. In places near the surface the sands are often cemented with iron oxide, causing some strata to resist erosion more than others. Thin bands of clay stone are also frequently found throughout the sands. They outcrop in various places in southern Madison County, where the Vicksburg limestone forms outliers on the upper Jackson. The exact stratigraphic position of the sands was first discovered in this vicinity. The following sections were obtained in Hinds and Madison counties, near the contact between the Jackson and overlying Vicksburg.

Just west of the house of Handy Washington (colored), in sec. 9, T. 7 N., R. 1 E., the Vicksburg, which overlies the upper Jackson, caps the top of the hill. At the base of the limestone are 2 feet of dark nonfossiliferous clay. Below this are 8 to 10 feet of fine, sharp-grained, white siliceous sand, with irregular horizontal bands of iron-stained sand containing small particles of mica and grains of glauconite. In appearance this is similar to some of the sand in the Grand Gulf, but in two different places the stratified sand lies unmistakably underneath the Vicksburg limestone. Below the sand and extending to the bottom of the hill is a bed of stratified clay of a general gray color, with a large number of iron-colored clayey bands and occasional layers of dark-blue clay. The whole is quite siliceous and contains much mica.

A good section of the upper Jackson is obtained along the road on the steep hill on the south side of a branch in sec. 16, T. 7 N., R. 1 E.

*Section of upper Jackson formation in sec. 16, T. 7 N., R. 1 E.*

| | Feet. |
|---|---|
| 6. Columbia and Lafayette at top of hill. | |
| 5. Alternating beds of Vicksburg limestone and marl | 30 |
| 4. Calcareous gray clay | 3 |
| 3. Gray, sandy, micaceous, stratified clay | 25 |
| 2. Reddish stratified sand containing bands of light-colored clay | 15 |
| 1. White, fine-grained sand | 10 |

Still farther north the white stratified sand often occurs in large deposits sufficiently pure for commercial purposes.

In a deep gully on the east-west road in the NW. ¼ sec. 2, T. 7 N., R. 1 E., the following section of the Jackson sands occurs:

*Section of Jackson sands in sec. 2, T. 7 N., R. 1 E.*

| | Feet. |
|---|---|
| 3. Columbia loam | 3 |
| 2. Lafayette | 2 |
| 1. Very fine-grained stratified sands containing mica, but no fossils or lime. The sand varies from cream white to pink in color and weathers into fantastic shapes | 10 |

Along Pearl River, between Jackson and Byram, the material at the top of the Jackson is decidedly sandy.

In a deep branch flowing westward in the southern part of sec. 15, T. 4 N., R. 1 E., the following relation exists between the Jackson and overlying Vicksburg limestone:

*Section of Jackson and Vicksburg formations in sec. 15, T. 4 N., R. 1 E.*

| | Feet |
|---|---|
| 4. Alternating beds of limestone and marl | 20 |
| 3. Chocolate-colored fossiliferous clay, containing crystallized gypsum and alum | 15 |
| 2. Pure lignite | ½ |
| 1. Green and chocolate-colored sands, cross-bedded, with occasional bands of clay, nonfossiliferous. | 20 |

The stratigraphic break between the Vicksburg and Jackson here seems to be the band of pure lignite which comes between the fossiliferous clay and the nonfossiliferous sand. Still farther down the river the sand at the base of the limestone shows at the water's edge, with a strong southward dip.

This sandy nature of the upper Jackson may be traced throughout the length of the Jackson-Vicksburg contact. The most complete section showing the contact between the two formations was obtained on the east side of the ridge on the Siwel and Bradie road, in the NE. ¼ sec. 22, T. 5 N., R. 1 W. The base of Vicksburg limestone here is 400 feet above tide.

*Section of Jackson and Vicksburg formations in sec. 22, T. 5 N., R. 1 W.*

| | Feet. |
|---|---|
| 5. Thin strata of white and yellow sand | 4 |
| 4. Yellow sand with thin bands of iron sandstone, one-eighth inch in maximum thickness. The whole is interbedded with white, chocolate, and purple clays, the latter 1½ inches thick | 5 |
| 3. Pure white sand | 2½ |
| 2. Black lignitiferous clay | 2 |
| 1. Pure white siliceous sand containing mica | 5 |

The remainder of the hill below is mostly covered with the wash from above, but where the strata are exposed they are highly stratified layers of sand gradually becoming more clayey near the base of the hill, and finally passing into a clay marl of the Jackson prairies at 350 feet above tide. Whether this sand is the same as the Red Bluff horizon, mentioned by Hilgard,[a] or not, it is impossible to say. Its stratigraphic position is the same, but no fossils have yet been found in the sandy strata.

## VICKSBURG FORMATION.

The Vicksburg formation, first studied by Conrad, occupies an area lying just south of the Jackson formation and of much smaller extent. It consists of a semicrystalline limestone in beds varying from 1 foot to 3 feet in thickness, alternating with beds of sandy fossiliferous marl of about the same thickness. The beautiful, well-preserved fossils of the Vicksburg are mostly found in these beds of marl. This highly interesting formation marks the end of the marine conditions of the Tertiary in western Mississippi. Its outcrop occupies a narrow band just south of the Jackson area and extends across the State from the typical outcrop at Vicksburg through Warren, Hinds, Rankin, Smith, Jasper, and Wayne counties into Alabama, where the Vicksburg and Jackson are inseparable on stratigraphic and paleontologic evidence, and are taken together and called the St. Stephens or White limestone. The Vicksburg outcrop is in most cases very narrow. Often the entire thickness is represented in one hillside. Where the country is more level the width of outcrop becomes greater, in places reaching 3 to 5 miles.

There is a marked difference in the character of the various beds of limestone. Usually those near the surface are more or less affected by weathering, and have therefore become soft and often yellow. Below the zone of weathering the rock is often hard blue limestone suitable for a building stone. In some places the hard blue limestone occurs near the surface and forms small bluffs along the streams.

There is no hard limestone of any consequence in the underlying Jackson and none in the overlying Grand Gulf, so that there is little possibility for mistaking the Vicksburg limestone. It is therefore a horizon easily recognizable in determining the dip of the Tertiary rocks.

The thickness of the Vicksburg is usually overestimated. There are 65 to 75 feet of the alternating limestone and marl beds represented in the bluff at Vicksburg. At no other place is there found as great a thickness in one continuous section. Below the limestone are 25 to 30 feet of lignitic clays and lignite. The full thickness of the formation is doubtless represented in the Vicksburg bluff.

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[a] Geology and Agriculture of Mississippi, 1860, p. 135.

An interesting feature of the formation is the fact that outliers, several miles removed from the main body of the formation, have been recently discovered. They occupy some of the highest land along the divide between Big Black and Pearl rivers, in the southern portion of Madison County. There are also two outliers at but a short distance from the main body of Vicksburg, one near Tinnin and the other near Brownsville. The details of the formation have been more thoroughly studied between Pearl and Big Black rivers than at any other locality. A careful study of the formation across the State would doubtless reveal a large number of outliers.

The localities of the Vicksburg outcrop across the State are numerous. There are in this formation a few hard strata of blue limestone, which resist the weathering agents, and where the country is somewhat hilly this hard limestone is almost always found at or near the surface (Pl. II, *A*, p. 12).

The most complete section of the formation at any one place is in the bluff at Vicksburg, given by Hilgard[a] as follows:

*Section of the bluff at Vicksburg.*

| | Feet. |
|---|---|
| 7. Bluff formation (loess) | 10-20 |
| 6. Orange sand (Lafayette) | 5-20 |
| 5. Alternating strata, 1 to 6 feet thick, of limestone and marl, containing the Vicksburg fossils and some bands of noneffervescent gray sand and clay | 60-65 |
| 4. Black lignitic clay and gray sand, with *Ostrea gigantea, Corbula alta, Natica mississippiensis, Cytherea sobrina, Madrepora mississippiensis* | 5 |
| 3. Gray or black lignitic clays and sand with iron pyrites; exuding salts and sulphureted hydrogen | 25 |
| 2. Solid lustrous lignite, with whitish cleavage planes | 3 |
| 1. White limestone of the Jackson group? | 3 |

All above No. 1 Hilgard places in the Vicksburg.

To show the alternating character of the limestone and marl an additional section is given below of the bluff about halfway between the cemetery and the city:

*Section of the bluff near Vicksburg.*

| | Inches. |
|---|---|
| 22. First stratum of limestone from top; overlain by loess | 10 |
| 21. Gray to yellowish marl | 9 |
| 20. Heavy-bedded limestone | 46 |
| 19. Indurated marl | 34 |
| 18. Thin, calcareous, plastic clay | 2 |
| 17. Indurated marl | 6 |
| 16. Clay similar to No. 18 | 2 |
| 15. Indurated marl | 5 |
| 14. Clay | 4 |
| 13. Hard limestone | 18 |
| 12. Clay and marl from one-half to 2 inches thick | 15 |
| 11. Indurated marl | 21 |
| 10. Limestone | 18 |
| 9. Gray marl | 18 |
| 8. Limestone | 18 |
| 7. Marl | 3-6 |
| 6. Hard limestone | 52 |
| 5. Marl | 6 |
| 4. Limestone | 27 |
| 3. Marl | 17 |
| 2. Limestone | 20 |
| 1. Marl | 45 |

This exposure is characteristic of the Vicksburg throughout the State. In places the limestone is more abundant, and in other places the marl. The limestone is more commonly found on account of the ease with which the marl breaks down into soil. In fact, the marl is rarely found except on bluffs, in wells, or on hillsides where erosion has been very rapid.

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[a] Geology and Agriculture of Mississippi, 1860, p. 141.

An interesting section occurs in the bluff 5 miles north of Vicksburg. The Yazoo and Mississippi Valley Railroad follows along the eastern edge of the Yazoo bottom near the bluff. The railroad track here has an elevation of about 100 feet above tide. At 130 feet above tide the top of the Vicksburg limestone occurs in a deep ravine. Here, as at many other places along the bluff to Vicksburg, fine springs of water come out on top of the limestone, most of which is covered by the wash from the bluff. Instead of the top of the limestone becoming higher to the north it appears to have about the same elevation as at Vicksburg; if anything, the top here is lower than it is at the cemetery. Resting on the Vicksburg limestone are 50 feet of white, fine-grained quartz sand with spots of iron oxide through it, the whole showing distinct lines of stratification. This is doubtless the sand of the overlapping Grand Gulf. It is clearly not Vicksburg, and is very distinct from the overlying Lafayette in the character of the sand and manner of deposition. Above the white stratified sand are 50 feet of Lafayette sand and pebbles. The basal part of the Lafayette contains a large amount of quartz and flint pebbles, stained with red oxide of iron. The pebble beds are not continuous, but appear in large lenses. The uppermost formation, capping the bluff, consists of about 90 feet of gray calcareous loess filled with snail and various land shells.

The gulch in which the above formations are so well exposed is 190 feet deep and is washed out in the shape of a large amphitheater. The walls stand almost perpendicular, and a glance around the sides shows the gray loess at the top and the laminated white sands resting on top of the limestone, separated by the orange-colored Lafayette sand, which contains large lenticular deposits of pebbles.

The Vicksburg occurs in numerous places between Vicksburg and Byram, where lime was made from this rock as early as 1836. The lime used in the first brick structure in Jackson is said to have come from the Byram kiln.

At the old Robinson quarry, about 4 miles southeast of Brandon, the following section of the Vicksburg was obtained:

*Section of Vicksburg formation 4 miles southeast of Brandon.*

| | Inches. |
|---|---|
| 14. Surface soil | 12-24 |
| 13. Ledge of limestone with edges of the rock rounded by the action of weathering agents | 12 |
| 12. Marl, with lime nodules | 12 |
| 11. Yellowish limestone | 18 |
| 10. Marl | 18 |
| 9. Yellowish rotten limestone | 9 |
| 8. Marl, below which the weathering agents have not penetrated | 18 |
| 7. Blue hard limestone used for quarry stone | 12 |
| 6. Gray to chocolate-colored marl | 21 |
| 5. Blue limestone, quarry rock | 18 |
| 4. Sandy gray marl | 12 |
| 3. Blue limestone | 12 |
| 2. Marl | 12 |
| 1. Limestone, bottom of quarry. | |

An interesting experiment was made with this rock to test the practicability of using the Vicksburg limestone as a building stone or for road metal. Machinery was installed for quarrying the rock and crushing it for the streets of Jackson. Work has been discontinued because, as reported, it was necessary to handle so much dead material to get the rock. The soil covering the rock will not average 2 feet thick, and the real difficulty is that the ledges of limestone, which average about 13½ inches thick, alternate with beds of indurated marl averaging 15½ inches, which is too hard or spongy to pick and not hard enough to blast. The ledges below No. 7 were used for road metal. Above this the rocks are soft and not suitable for this purpose.

In Smith County, still farther southeast of Brandon, the Vicksburg assumes a different phase from that which it presents to the west. South of Pineville the limestone is quarried from the ground and used locally for building chimneys and foundations for houses and barns. When first taken out of the quarry the stone is so soft that it can be sawed into any shape by hand. It is then left in the open air, where it soon becomes hard. It is in most places free from fossils and when dry is almost pure white.

At Vossburg the hard blue ledges of the lower Vicksburg occur in the hills one-half mile northwest of the town. To the northeast the low prairie land of the Jackson continues to near Pachuta.

> On the Chickasawhay [says Hilgard [a]], between Red Bluff and the latitude of Waynesboro, both marls and limestones crop out with frequency; the same is the case on the creeks on the east side, as on Cakcheys Mill Creek and Limestone Creek, especially near the mouth of the latter, at the foot of the hill on which Dr. E. A. Miller lives, the most southerly outcrop of the calcareous Eocene [now called Oligocene] on the Chickasawhay.

### PASCAGOULA FORMATION.

Along Chattahoochee River in Florida a series of Oligocene beds overlain by a succession of strata containing Miocene fauna has been described by D. W. Langdon as Miocene. On paleontologic and stratigraphic evidence the upper Oligocene beds have been shown by Dall [b] and Stanley Brown to rest directly upon the lower Oligocene or Vicksburg limestone. The same Oligocene beds have been found by Dr. E. A. Smith on Conecuh River, near Roberts, Ala. Deep borings at Mobile, Ala., have shown the Oligocene beds at a depth of 1,550 feet below the surface.

Nowhere in Mississippi have the Miocene beds so far been discovered. However, on the banks of Chickasawhay River, a few miles above the mouth of Leaf River, L. C. Johnson has found a Tertiary bed of marl containing large oysters (*Mactra lateralis* Say), numerous small *Gnathodon johnsoni*, and other forms. These fossils were referred to Dr. W. H. Dall, who doubtfully correlated the bed with the aluminous clay horizon of the Alum Bluff section, which is placed in the Miocene.

The exact age of the bed has not been determined, but Mr. Johnson has given it the name Pascagoula and refers it to the Miocene.

Dr. E. A. Smith, who visited the locality later, in speaking of the fossiliferous bed, said:

> It, at the type locality, is covered by the sands, with silicified tree trunks and lignitized wood belonging to what Hilgard called Grand Gulf, but the material in which the shells are found may be the same blue clay assigned to the Grand Gulf, lower bed, and occurring along the bank of Chickasawhay River from Bucatunna down to its confluence with Leaf River. Whether, therefore, this Pascagoula bed belongs to the Grand Gulf or not, it is below a great mass of material that has never been questioned as being Grand Gulf. At Mobile this same shell bed is penetrated to a depth of 700 feet, or thereabouts, and several hundred feet above the Chattahoochee Miocene [now called Oligocene], which is reached at 1,550 feet. In Mobile County, as in Mississippi, this shell bed is below a great mass of sands and clays that have been considered Grand Gulf.
>
> So, as a matter of fact, there come in between the Vicksburg and Lafayette, both in Alabama and Mississippi, a great series of marine Tertiary strata, of Miocene age, at least in the lower beds, and these marine Miocene beds and the Pascagoula (whatever its age may be) lie below much, if not all, of what Hilgard designated as Grand Gulf, and what I take it is actually Grand Gulf. As before mentioned, nothing is known to overlie the Grand Gulf beds older than the Lafayette, while the Grand Gulf is certainly known to overlie at least the Miocene, and, as many of us think, any other later Tertiaries if they exist along the Gulf border.

Owing to the limited area of outcrop the formation is not shown on the map.

### GRAND GULF GROUP.

The Grand Gulf group, as the term is here used and mapped, is possibly not a homogeneous series of beds, but may include formations of different age. It is certain, however, that everything here included in the Grand Gulf is younger than the Vicksburg limestone and older than the Lafayette or "Orange sand" formation.

At the type locality of the Pascagoula formation, as well as at Mobile and other points, the Pascagoula beds are overlain by Grand Gulf beds; but further field work will be required before the relation of these two series in other areas can be stated with certainty. Such later work may require a redefinition or limiting of the term Grand Gulf. At present, however, the term is here used in the sense in which it was proposed by Hilgard, for a particular series of clays and sands overlying unconformably the Vicksburg and other beds, and overlain in places by the Lafayette, Port Hudson, and loess.

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[a] Geology and Agriculture of Mississippi, 1860, 146.

[b] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1898, pp. 327-348.

The Grand Gulf was first studied and named by Wailes from the type locality at Grand Gulf, Miss. He included in the Grand Gulf sandstone the interbedded clays, which he regarded as "the decomposed portions of the imperfectly formed rock." [a]

At Grand Gulf, the type locality, at Mississippi Springs, and at Raymond, mentioned by Wailes,[b] the sandstone occurs in ledges interbedded with white plastic clays. He further adds:

> At many points within the scope I have mentioned the rock crops out in the beds of the watercourses and upon the sides of the ridges, exhibiting, as in that in the Mississippi bluff, such an identity of character as to induce me to characterize it wherever met with as the Grand Gulf rock.

The sandstone of Fort Adams, or Davion rock, as it is called by Wailes—

> is an argillo-siliceous composition of a dingy-white color in the mass, containing a small portion of sand, cemented together and tinged by a brownish-red metallic oxide, which pervades it in irregular and distorted veins and which, forming the hardest portions of the mass, gives the weathered surface a very rough and nodular character.

Wailes describes the Grand Gulf in T. 5 N., R. 1 E., near Wilsons Ferry, on Homochitto River, as follows:

> The more compact arenaceous portion of the stratum is here about 3 feet in thickness, with about the same thickness, above and below, of the more argillaceous and crumbling material, which, in wet weather forms a very tenacious white pasty clay, rendering this a very formidable pass to the wagoners on the road, who have given to the ridge on which this ledge runs the name of the Devil's Backbone.

It is evident from the above quotations that it was the intention of Wailes, who first used the name Grand Gulf sandstone, to include in the term the clays of the same age.

At Star, Miss. (see p. 42), clays are interbedded with the sandstone and form the principal part of the Grand Gulf in some of the outcrops along the railroad track. Clays are likewise prominent in the Grand Gulf at Raymond, Byram, Florence, and numerous other localities originally included in the Grand Gulf area.

The Grand Gulf is made up of unconsolidated sands, siliceous and aluminous sandstones, and clays. The sandstones are usually white to light-yellowish gray in color, and but slightly cemented. They are composed of sharp grains of silica, with more or less clayey material and iron pyrites. Near the surface the oxidation of the iron pyrites in the sandstone gives it a spotted rusty to yellow color and renders it undesirable for a building stone. In places the sandstone is little more than a mass of indurated, uncemented sand which can be dislodged from its original bed with a spade. In other places it is much harder, even approaching a quartzite.

The sandstones interbedded with clays of this group are particularly common in the northwestern part of the area—that is, northwest of a line drawn from Fort Adams to Raleigh; southeast of such a line sandstones are very rare, and the group consists of bluish to black clays (in places almost shales) and clayey sands.

Throughout the Grand Gulf, particularly in the northwestern or sandstone area, crystallized gypsum and common salt, with more or less magnesian salt, are often found. "This," says Doctor Hilgard,[c] "is the case, even with many of the solid sandstones, which on exposure to the weather become covered with efflorescences of salts; and it is to this peculiarity, no doubt, that their want of durability is to a great extent to be attributed."

The Grand Gulf underlies most of that part of Mississippi south of a line drawn as follows: Starting on Mississippi River a few miles south of Vicksburg, it runs parallel to and a mile or so south of the Alabama and Vicksburg Railway and passes a short distance north of Raymond. Here the boundary line between the Vicksburg and Grand Gulf bends rather abruptly to the southeast, crossing the Illinois Central Railroad between Terry and Byram. The line then turns northeastward, passing through Monterey to Brandon, at which point it finally assumes a southeasterly direction, continuing thence through Daniel, Raleigh, Vossburg, and Waynesboro into Alabama. All of the State south of this line, except a narrow belt of Port Hudson clays, which border the Gulf coast in Hancock, Harrison, and Jackson counties, is occupied by the Grand Gulf group.

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[a] Wailes, Agriculture and Geology of Mississippi, 1854, p. 213.
[b] Op. cit., p. 217.
[c] Geology and Agriculture of Mississippi, 1860, p. 148.

The thickness of this group is not definitely known, but from some deep-well records along the coast the drill is supposed to have penetrated the Grand Gulf at 750 to 800 feet. At this depth some fossils were found, which L. C. Johnson refers to the underlying Pascagoula marls.

Lincoln, Copiah, Hinds, Simpson, and Rankin counties, and the counties along Mississippi River from Fort Adams to Vicksburg, contain the only outcrops of the sandstone, which in these localities alternates with white to bluish plastic clays.

The following section from the type locality, Grand Gulf, is taken from Hilgard's Geology and Agriculture of Mississippi, page 148:

*Section of the bluff at Grand Gulf.*

| | | Feet. |
|---|---|---|
| 12. | Calcareous silt of the Bluff formation, forming the hilltops | 60–70 |
| 11. | Grand Gulf sandstone, in ledges 10 inches to 2 feet in thickness; stratification often discordant and curved | 14 |
| 10. | Gray sandy material, sometimes soft sandstone, with an argillaceous cement, alternating with harder ledges, 6 to 10 inches thick, of friable, whitish sandstone | 15 |
| 9. | Solid whitish sandstone of good quality | 2½ |
| 8. | Greenish-gray clay, with white veins of carbonate of lime | 2½ |
| 7. | Soft white sandstone | 1 |
| 6. | Grayish-yellow pipeclay | ½ |
| 5. | Dark-gray, brittle sandstone | 1 |
| 4. | Gray, semiindurated clayey sand | 3 |
| 3. | Gray and yellowish sands and clays, semiindurated, interstratified | 17 |
| 2. | Semiindurated gray sand | 3 |
| 1. | Greenish-gray clay, with veins of carbonate of lime | 2 |

Doctor Hilgard mentions numerous other outcrops of Grand Gulf in this region, including several localities near Rocky Spring where beds of lignite occur. Wailes found a bed of lignite 2 feet thick between two ledges of sandstone; also in sec. 11, T. 4 N., R. 3 W., and at Partins Ferry, Hinds County. Alternating beds of clay and sandstone are reported by Hilgard at Fayette, Jefferson County, also in Franklin, Copiah, Hinds, Rankin, and Simpson counties.

The following section from a bluff on the south side of Richland Creek, in sec. 12, T. 4 N., R. 2 E., shows the character of the lower 100 feet of the Grand Gulf:

*Section of Grand Gulf beds in sec. 12, T. 4 N., R. 2 E.*

| | | Feet. |
|---|---|---|
| 4. | Ledges of Grand Gulf sandstone, 12 to 15 feet thick, alternating with gray clays on side of hill. | (?) 50 |
| 3. | Dark-blue plastic clays, containing more or less sand and becoming lighter colored near bottom of hill | 60–70 |
| 2. | Ferruginous sandstone containing greensand | ½ |
| 1. | Calcareous greensand marl, with badly preserved fossils, extending to bed of creek | 5 |

The ledge of ferruginous sandstone marks the division between the Grand Gulf and the underlying Vicksburg. Similar outcrops showing the lower clayey portion of the Grand Gulf overlying the Vicksburg formation were seen 1 mile south of Pearson, Hinds County.

A section of the Grand Gulf at Star, Rankin County, is very similar to that at Grand Gulf. The sandstone comes to the surface in the hills at and near Star. In the railroad cut 100 yards south of the station there are 5 feet of soft rotten sandstone with harder layers from 3 to 6 inches thick through it. This is overlain by about 10 feet of gray to white plastic clay containing some sand. The following section was obtained in the hills to the southwest, where the material is at a higher elevation than the outcrop along the railroad:

*Section of Grand Gulf beds near Star.*

| | Feet. |
|---|---|
| 3. Heavy-bedded sandstone, in places barely cemented together so that great caves have been made in the hill by the action of weathering agencies | Thickness undetermined. |
| 2. Gray clay | 10 |
| 1. Hard white sandstone with bluish streaks through it. In places the stone is very compact and will take a slight polish. The larger part of it, however, is a loosely cemented, coarse-grained sandstone containing a small amount of mica and small irregular particles of clay which were washed into the matrix before it was hardened. The clay particles seem to have shrunk, leaving small irregular openings in the clay mass | 15 |

Two specimens of this sandstone were tested in the engineering laboratory of Purdue University with the following result:

*Crushing strength of Grand Gulf sandstone from Star.*

| | Pounds per square inch. |
|---|---|
| Sample No. 1, 4 by 4 inches | 2,740 |
| Sample No. 2, 4 by 4 inches | 3,260 |

South and east of the line above mentioned the sandstones are wanting and the formation is essentially a series of indurated, laminated clays and sands of various characters, from the white plastic pottery clays to the less pure lignitic and gypsiferous ones containing lignitized tree trunks and in places beds of pure lignite.

Four outcrops of Grand Gulf clays on Chickasawhay and Pascagoula rivers are mentioned by Doctor Hilgard. The northernmost of these is on Col. Sam Powe's place, 2 miles south of Winchester, Wayne County. At this locality are well-preserved lignitized trunks of trees and old stumps which have been covered with the "ancient soil" absolutely on the spot where they grew. Above the old trunks and stumps are thin seams of sandy clay, between which are successive layers of leaves. The whole is covered with 20 feet or more of Lafayette sand. Most of the submerged trees, according to Hilgard, are dicotyledons; some are conifers and some palms.

To the west from Chickasawhay River a very plastic clay immediately underlies the Lafayette sands and overlies the darker lignitic clays as found along the river. This plastic clay is found in numerous wells beneath the Lafayette and likewise outcrops along the streams where the Lafayette has been removed. Deposits of leaves and vegetable matter similar to those mentioned above were observed by L. C. Johnson along Leaf River near Augusta, at Rawles Springs in the northwestern part of Perry County, and at Carpenter Bluff, Perry County. At the last place the Lafayette, according to Johnson, overlies about 50 feet of gray sandy clays, below which are 14 or 15 feet of blue mud filled with leaves and rotten logs.

One and a half miles north of Hattiesburg, on the Gulf and Ship Island Railroad, the clay is characteristically developed. It is here very plastic, free from sand, and varies in color from white to blue, gray, and cream. It is nonfossiliferous and free from any lime concretions. It is very similar to the clay farther west along Pearl River, except that the latter clay has numerous lime concretions through it.

Below the variegated plastic clay so common at the surface at Hattiesburg the strata contain more or less sand, lignitic material, and plant remains. Ferruginous nodules and in places more or less iron pyrites and numerous salts are present, which give rise to a great variety of mineral springs and inferior well waters.

The plastic Hattiesburg clay passes underneath the younger formations to the south. In some of the deep wells along the coast a bluish-green plastic clay, with a maximum thickness of 150 feet, is reported to be struck from 450 to 550 feet. Whether this is the same clay as that coming to the surface at Hattiesburg it is impossible to say. With a southward dip of the strata of 6 to 8 feet per mile the base of the Hattiesburg clays would be penetrated at Mississippi City at a depth of about 600 feet. It has not been possible with the present data to ascertain the southward dip of the Grand Gulf, but it is very probable that 7 to 10 feet per mile is an average estimate. Regarding the dip of the Grand Gulf Hilgard[a] said that "the position of the Grand Gulf strata can rarely be shown to be otherwise than nearly or quite horizontal on the average, although in many cases faults or subsidences have caused them to dip, sometimes quite steeply, in almost any direction."

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[a] Am. Jour. Sci., 3d ser., vol. 22, July, 1881.

After a study of the Grand Gulf strata along Chickasawhay River north of its confluence with Leaf River Doctor Smith, in an unpublished essay on the later Tertiary strata, reaches the conclusion that there is but little, if any, dip to the Grand Gulf. He further says, however, that the calcareous strata outcropping on the Chickasawhay a few miles above the mouth of Leaf River and bearing Miocene fossils at the base of the lignitic clays which Hilgard called Grand Gulf, are found in a well at Mobile at a depth of 700 feet. The confluence of these two rivers is but about 25 miles north of the latitude of Mobile. On this evidence, therefore, and apparently somewhat at variance with the statement made by Smith that the strata along the Chickasawhay "are nearly or quite horizontal," there is a southward dip of at least 20 feet to the mile, ample allowance being made for difference in elevation of the two places. A much greater southward dip is obtained from beds containing Miocene fossils on Chattahoochee River, extending from Chattahoochee Landing down to Alum Bluff. "The Chattahoochee Miocene [Oligocene of this paper] beds," says Smith, "outcrop at least in one place in Alabama, viz, on Conecuh River, in Escambia County, above Roberts, and about Roberts post-office. But deep borings in Mobile (30 miles south of Roberts) have shown that the very same beds that occur along Chattahoochee River lie at a depth of 1,550 feet, more or less, below the surface. Many well-preserved shells brought up from this depth afford ample proof of this." If the Miocene beds continue westward across Alabama from Chattahoochee River, which is very probable, the southward dip is thus something like 50 feet to the mile.

It seems probable, then, that there is a very steep southerly dip to the older Tertiary, including the Chattahoochee Oligocene and overlying Miocene beds, but that on coming upward to the Grand Gulf strata the southerly dip has almost and in some places entirely disappeared. The deposition of the Grand Gulf strata did not immediately follow that of the Miocene beds, but there is a marked unconformity and a long time interval between the two. There was a marked subsidence of the land during the early part of the Grand Gulf period, so that Grand Gulf strata overlapped not only the Miocene beds, but likewise the Vicksburg, Jackson, and Claiborne, and extended the blanket far to the north, in places overlapping the Cretaceous.

Smith, in the above-mentioned essay, says that—

> Hilgard saw no contact of the Grand Gulf along its northern border with anything below it other than the Vicksburg; but in Alabama, to the east of the Louisville and Nashville Railroad, the northern border of this formation takes a turn toward the northeast, and I have seen it resting on not only Vicksburg, but in turn on the Claiborne, on the Buhrstone, and on the Lignitic formations, even the lowest of them at Clayton, in Barbour County; and farther east in Barbour County and still more in Georgia the Grand Gulf beds lap over well upon the Cretaceous beds. Certainly, therefore, the order of succession going southward can not be taken as determining the geologic succession.
>
> In Alabama the blanketing character of the formation is very clearly seen, for in the different parts of the northern border of its occurrence erosion has exposed the underlying Tertiary beds, which are Vicksburg, Claiborne, Buhrstone, Lignitic Clayton, and even Cretaceous, according to the locality. Farther south erosion in similar manner has exposed the underlying Miocene [Oligocene] in the vicinity of Roberts, Ala., and along Chattahoochee River. We may state further that at Mobile, where the Grand Gulf beds occupy the surface, capped, it is true, with the Lafayette, the deep wells have demonstrated the existence at 700 feet below the surface of the Pascagoula bed and at 1,550 feet the Chattahoochee Miocene [Oligocene], fully determined by the well-preserved shells. At present, then, the map of Mississippi must remain, as regards the Grand Gulf, practically as Hilgard has given it, with the understanding that the other marine Miocene deposits in all probability underlie and are hidden by it as by a blanket.

## QUATERNARY.

### LAFAYETTE FORMATION.

The Lafayette formation was first described by Hilgard in his Geology and Agriculture of Mississippi, in 1860, under the name of Orange sand. The name had previously been used by Safford[a] of Tennessee, for the present Lafayette, but he included in it the present Wilcox and the whole was referred to the Cretaceous. In 1891 W J McGee [a] published a paper on the Lafayette formation. He likewise included in the term Lafayette 200 feet or more of the Wilcox which belongs to the Eocene. The vast deposits of pottery clays in the vicinity of Holly Springs, Miss., which contain numerous impressions of leaves of Tertiary plants, were improperly placed in the Lafayette by McGee. The term as used in this report is restricted to the thin veneering of iron-stained pebbles and sand which overlaps unconformably all the other formations of the State, from the older Paleozoic rocks along Tennessee River to and including the Grand Gulf group of the late Miocene, and underlies the Port Hudson in southern Mississippi. In age it is, therefore, between the Grand Gulf and the Port Hudson and loess. In the south the Lafayette is overlain by the Port Hudson clays, while in northern Mississippi the loess, when present, rests directly on the Lafayette, and the Port Hudson is absent. East of the typical calcareous loess in western Mississippi the yellow loam or upper member of the loess immediately overlies the Lafayette. In the central and eastern parts of the State, where not carried away by erosion, the Lafayette occupies the surface, as the loess does not extend more than 100 miles from Mississippi River.

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[a] Geologic Reconnaissance of Tennessee, 1856, pp. 148, 162.

The Lafayette is a fresh-water deposit, which is composed principally of dark-red to faint-orange, coarse, round-grained sand, and in places contains more or less clay and waterworn pebbles. The pebbles are of two kinds (a) chert and limestone containing numerous Paleozoic fossils, such as fenestellids, favosites, pentremites, and other forms; (b) less numerous but more resistant quartz pebbles. The former class is much more abundant. They were washed into the Lafayette waters from the adjacent Paleozoic hills, as their fossils clearly indicate. The nearness of their origin is further indicated by the angular character of the pebbles, some of them barely having their sharp corners worn off. The quartz pebbles are all round or egg-shaped and are much smaller than those of Paleozoic origin. They have been transported over a greater distance and are consequently more worn. They are doubtless the fragments of the great northern drift carried southward by great volumes of cold, fresh water at the close of the Glacial epoch.

The thickness of the formation varies from a knife-edge to 50 feet. The latter, however, is very rare. It is more often found to be less than 10 feet thick.

In Tishomingo and Itawamba counties the Lafayette contains large deposits of waterworn pebbles of flint, chert, and quartz. Another belt of similar material, but somewhat different in the shape of the pebbles, occurs along the eastern edge of the loess formation, comprising the counties of De Soto, Tate, and Yalobusha. The pebbles of the northeastern area are oblong or egg shaped and contain more quartz, while those of the western area are worn into a more rounded form. Still another belt, which is practically a prolongation of the western belt, is found in the southern part of the State, the main line of the Illinois Central Railroad following along the outcrop of the gravel beds from Jackson to the Louisiana border.

The Lafayette was deposited upon a deeply eroded surface of the older formations, which accounts in part for the irregularity of its thickness. In some places gullies and ravines, cut in the old formations and filled with Lafayette, have been exposed. Since the deposition of the Lafayette there has been a large amount of erosion and in many areas the whole formation has been removed. In the Selma chalk and Porters Creek areas the Lafayette is generally absent, when present it occurs in small isolated patches. East of the Selma chalk area there is more or less Lafayette covering the Eutaw and Tuscaloosa and overlapping onto the Carboniferous. In northern Mississippi, particularly in Marshall and Lafayette counties, where the formation was first described and named, the Lafayette, when present, is but a few feet thick, but in most places it is wanting. It thickens to the south, reaching its maximum thickness, said to be 200 feet, in southern Mississippi. No such thickness, however, was observed in the course of the present work.

In various localities over the State the iron in the Lafayette has cemented the yellow or red sands into a ferruginous sandstone, which contains more or less iron and is often mistaken for pure limonite or brown hematite. These deposits are in every case of very shallow depth, but often extend over large areas. The ferruginous sandstone is always formed immediately above a bed of clay or some material which checks the downward flow of water. The water passing through the Lafayette takes up iron oxide in solution, and being checked by the underlying impervious bed deposits the iron oxide, thus cementing the sands into a compact mass. This mass is constantly increased by the addition of more iron from the iron-charged waters. Gradually the overlying material is carried away until the ferruginous sandstone is reached; this resists the action of erosion and forms a scarp on the tops and sides of many hills.

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[a] Twelfth Ann. Rept. U. S. Geol. Survey, pt. 1, 1891, pp. 353-521.

Where the Lafayette is thick it is the source of a very desirable and easily accessible supply of potable water. The great amount of sand in the formation forms a natural filter for the water. Many of the springs and the shallow wells of the State derive their water from the Lafayette.

### PORT HUDSON FORMATION.

In the American Journal of Science, volume 47, 1869, page 79, Doctor Hilgard first described the Port Hudson formation at the type locality, Port Hudson, Miss. The following sections were made by him along the river near the town:

*Sections of Port Hudson formation near Port Hudson.*

| No. | Near sawmill, Port Hudson. | | Midway between Port Hudson and Fontania. | |
|---|---|---|---|---|
| | Material. | Thickness. | Material. | Thickness. |
| | | *Feet.* | | *Feet.* |
| 6 | Yellow surface loam | 4-6 | Yellow loam, sandy below | 8-10 |
| 5 | Yellow hardpan | 25 | White and yellow hardpan<br>Orange and yellow sand, sometimes ferruginous sandstone, irregularly stratified. | 18<br>8-15 |
| 4 | Heavy greenish clay | ........ | Heavy greenish or bluish clay | 7 |
| 3 | Gravel, sand, and clay in irregular bands, like river alluvium; with pebbles, driftwood, leaves, and mastodon bones. | 6 | White indurated silt or hardpan | 18 |
| 2 | Heavy greenish or bluish massy clay, similar to No. 4. | 25 | Heavy green clay, with porous calcareous concretions above, ferruginous ones below; some sticks and impressions of leaves. | 30 |
| 1 | .................................... | ........ | Brown muck and white or blue clay, with cypress stumps. | 3-4 |

> At the stage of extreme low water [says Hilgard] prevailing at the time, the stump stratum (No. 1) was visible to the thickness of 10 feet at its highest point, showing several generations of stumps above one another, also the remnants of many successive falls of leaves and overflows. The wood is in a good state of preservation; no prostrate trunks are to be seen at present.
>
> The main clay deposit (No. 2) varies but little in general character; although very solid, its tendency to cleave into prismatic forms renders it very liable to "cave" into the river. The upper portion of the stratum, especially near its southern end, contains strings of calcareous nodules, on stratification lines 8 to 12 inches apart. No fossils save rare impressions of leaves.
>
> No. 3 is exceedingly variable. At the northern end of the outcrop it is a narrow band of swamp deposit; at the first of the profiles given it bears the character of a sandbar; lower down it returns to that of a swamp deposit; still below it is represented by a fine white silt, without a trace of vegetable remains. Lower down again a lignitic layer appears at its base, with leaves and fruit of living species of lowland trees; while near Fontania it is again a sandbar, with an abundance of prostrate trunks of driftwood, coarse sand, and pebbles.
>
> The green clay stratum (No. 4) varies little, either in thickness or composition, and, like the stump stratum (No. 1), forms a convenient level of reference.
>
> The hardpan (No. 5) I conceive to be the more immediate representative of the loess proper, with which it is connected by gradual transition, though at times greatly resembling some of the materials of the Lafayette. It is void of fossils.

Doctor Hilgard and others regarded the clays and sands of the Yazoo delta as belonging to the Port Hudson formation; likewise deposits bordering on the Gulf coast. In correlating the outcrop at Port Hudson with the material of the Yazoo delta, he further adds:

> The stump stratum (No. 1), however, as appears from numerous data collected by myself or contained in Humphreys and Abbot's Report on the Mississippi River, exists at about the same level —that is, near that of tide water—not only over all the so-called delta plain of the Mississippi, but also higher up, perhaps as far as Memphis, and all along the Gulf coast, at least from Mobile on the east to the Sabine River. Wherever circumstances allow, the overlying clay stratum (No. 2) is also observed.

In the report on the Coastal Plain of Alabama, page 40, Dr. E. A. Smith, in speaking of the eastward extension of the Port Hudson along the Gulf coast, says:

> Whether there is any real genetic difference between the loess and the Port Hudson other than the order of deposition, the lowest and therefore the oldest members of this section have received the latter designation and there is no good reason for discussing it here and seeking change. It is these members from 1 to 4, inclusive [of the Port Hudson sections of Hilgard], that we find spreading along the northern shore of Lake Pontchartrain and underlying the alluvium of Pearl River, modified and reappearing beyond, and underlying and constituting the terrane of all the region of the "Pine Meadows," together with a variable fringe to the northward, covered by washings from the sand hills, and an undefined portion of the territory covered by the coastal sands, above more definitely called "Biloxi."

From Hilgard's sections there is little room for doubt regarding the order of deposition of the Port Hudson and the overlying loess. In both sections, made from two localities 1 mile apart, there is practically the same order of strata, with the loess or hardpan above what he describes as Port Hudson proper.

As will be seen from the above quotation, Smith has suggested the possibility that the entire section, as given by Hilgard, belongs to the loess and that the lower portion has received the name Port Hudson.

The section as above given is clear enough as it stands and shows the relation of the Port Hudson to the loess; but the correlation of the so-called Port Hudson of the upper Mississippi or Yazoo delta offers some difficulties which have not at present been removed. This correlation has been made chiefly from the fact that there are logs and decayed vegetation found in the clays of the Yazoo delta, and likewise calcareous concretions. The decayed logs, or "stump stratum," according to Hilgard, occur at about tide level throughout the Yazoo delta as well as farther south. At Port Hudson, Miss., the loess rests directly upon the Port Hudson formation, but farther north the loess caps the hills on the east rim of the Yazoo delta at 100 feet or more above the so-called Port Hudson. Finding the Port Hudson clays in the bottom and the loess on the east rim of the Yazoo delta 100 feet higher would, according to Hilgard's theory, necessarily imply that the entire Mississippi Valley contained at one time 100 feet more of Port Hudson than it does to-day. Succeeding this was a time of vigorous degradation, carrying away the loess and 100 feet of Port Hudson, until the present level was reached. This would mean that the vast bottom land in northern Mississippi, northeastern Arkansas, and Louisiana attained its present surface form by destructional rather than constructional agencies.

The Yazoo delta and the corresponding areas on the west side of the Mississippi, previous to the deposition of the present materials, were scoured out 50 to 100 feet deeper than they are at present. This is clearly proved by finding old logs, bark, and river gravels at these depths. The loess, Port Hudson, Lafayette, and portions of the Tertiary were removed by degradation. Then began the deposition which has continued until the present level has been attained.

A study of these later formations in northeastern Arkansas during the spring of 1905 has revealed the fact that the present levels of this vast plain have been reached by a constructional and not by a degradational agency. Much of the so-called Port Hudson of the lowlands appears to be the reworked products of the loess, which still caps the adjacent hills and Crowley Ridge.

If the materials of the Yazoo delta are considered to be Port Hudson, then, from the order of the strata in the south, the Lafayette must underlie it. While gravels are found at various depths in the wells over the delta, they do not resemble the typical Lafayette pebbles on the hills to the east. The pebbles found in wells throughout the delta are generally small and white, while those of the Lafayette are invariably iron stained and often quite large. The interpretation resulting from the present survey is that the vast so-called "Port Hudson" deposits of the Yazoo delta are of much more recent date than the Lafayette, Port Hudson, loess, and yellow loam, and are, to a greater or less degree, the reworked products of these formations.

## LOESS.

This highly interesting formation was first recognized in this country along the lower Mississippi by Sir Charles Lyell in 1846. In 1854 Wailes, in the report on the Agriculture and Geology of Mississippi, mentions the loess as occurring at various places along the Mississippi. The following year G. C. Swallow, State geologist of Missouri, described the loess of Missouri River and gave it the name of Bluff formation. Hilgard used the same term for the loess in Mississippi in 1860. It has since received the attention of Chamberlin and Salisbury, McGee, Mabry, Binney, and Shimek. The latter, in Bulletin No. 4, vol. 5, of the State University of Iowa, presents a lengthy discussion of the loess at Natchez, Miss., ascribing its origin to æolian agencies. His conclusions are based entirely on the fauna found in the loess. At Natchez and Vicksburg, the two localities where he saw the loess, he found the material a highly calcareous, homogeneous mass, nonstratified and containing numerous land snails and other terrestrial forms.

The loess is divisible into two distinct parts—(a) the fine, calcareous, gray to buff-colored, silty clays, containing numerous lime concretions and iron tubules, besides a great variety of fresh-water and land shells; (b) noncalcareous yellow to brown loam, void of shells. The latter has been described by Hilgard as the yellow loam.

The hypsometrical relation of these two members varies in different places, as the following will show. Shimek[a] says:

> The loess [at Natchez] is uniformly the uppermost deposit, forming the immediate subsoil on the ridge on which Natchez is located. Underlying it in most of the exposures is the yellow or brown loam, which closely resembles loess, but is not fossiliferous and is usually of a deeper red color, though sometimes practically indistinguishable from it.

In northern Mississippi Hilgard describes the yellow loam as overlying the loess. McGee places the yellow loam above the calcareous loess, but adds:

> The order of the first two members might be reversed with equal propriety in the southern portion of the embayment; for the loess is but a phase of the loam and is frequently underlain as well as overlain by the loamy deposits.

Mabry refers to the yellow loam and loess as being not only homotaxial but synchronous as well.

From observations made at various places in Mississippi, Tennessee, and Arkansas, the writer has reached the conclusion that all the above statements are correct. The yellow loam is only a modification of the typical loess. In other words, the loess changes in character from a gray, calcareous, silty material filled with shells to a reddish or yellow clay free from shells and calcareous matter. The positions of the two are interchangeable. At numerous places along Crowley Ridge, in Arkansas, the yellow clay both underlies and overlies the typical calcareous loess, but there are no lines of division between the two; one grades insensibly into the other.

In the vicinity of Bolton, Miss., and along Big Black River it is often impossible to draw any line where the loess ends and the yellow loam begins. The calcareous loess gradually blends upward into the more clayey loam.

It is frequently the case that the yellow loam is entirely wanting, as at Helena, Ark., where the entire bluff is capped with the fossiliferous calcareous loess, which here shows faint lines of stratification. Still farther north, along Crowley Ridge, in Arkansas, the calcareous loess is wanting and the buff to yellow clay is at the top of the bluff overlying the Tertiary.

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[a] Bull. No. 4, vol. 5, State University of Iowa.

The loess is found skirting the east bank of Mississippi River south of Vicksburg and to the north bordering the bluffs which form the eastern rim of the Yazoo delta. The deposit is thickest near the river and gradually thins out to the east, finally disappearing entirely. In some of the hills east of Grenada the loess or yellow loam covers the sides and base of the hills, but does not reach to the top. The hills thus stand out like islands, surrounded by loess sediment.

Where characteristically developed, as at Vicksburg, Natchez, and Yazoo City (Pl. III, *B*, p. 18), the calcareous portion of the loess has the tendency to stand up in perpendicular walls for long periods of time.

In northern Mississippi the upper, nonfossiliferous yellow clay loam extends 50 miles or more east of the Yazoo bluffs. It forms the highest stratum as far east as Marshall and Lafayette counties and overlies the Lafayette when present. Only the lower member is shown on the map.

### RECENT ALLUVIUM.

The most recent deposits of the State, occurring along the present streams, are not shown on the map, but have been mapped with the underlying formations.

## MINERAL RESOURCES OF MISSISSIPPI.

### PRESENT DEVELOPMENT.

The development of the mineral resources of Mississippi has been so slow that the total annual mineral product of the State is still of little importance compared to her vast agricultural output. The most accurate figures obtainable show that for the past four or five years the annual mineral production of Mississippi has varied from about $500,000 to about $700,000. About nine-tenths of this production comes from the clay-working industries—bricks, tiles, stoneware, and pottery. Next in importance at the present time are the mineral waters of the State, which contribute materially to her production. A small amount of stone is quarried within her limits, and comparatively unimportant amounts of ocher, glass sand, iron ore, etc., have been shipped at various times.

### FUTURE PROSPECTS.

The slow development of the mineral resources of the State is due, in large part, to the fact that no State geological survey has been in existence. It is known that Mississippi possesses, for example, large deposits of excellent raw material on which to base very extensive cement and clay-working industries. These deposits have never been accurately mapped or tested, however, and so little is known concerning the actual distribution and composition of these raw materials that capital is naturally averse to taking chances in developing them. The energetic prosecution of a State survey would have the effect of advertising the presence of such resources and of determining accurately their distribution, their quality, and their uses.

Aside from the clay and cement resources of Mississippi, several other mineral products would seem to promise future importance. Deposits of iron ore are known to occur, and tests of their quantity and quality would be of great value to the State. Ocher, glass sand, tripoli, and fuller's earth occur, apparently in deposits of workable size. The lignites of the State are worthy of attention, particularly for local use in clay works, etc.

Aside from iron, no metallic ores are known to occur in Mississippi in deposits of workable size, and the prospect of finding such deposits seems very poor.

The calcareous and greensand marls of the State deserve study, particularly in view of the great importance of Mississippi as a cotton producer. At present every pound of fertilizer used on Mississippi plantations is imported from other States. It seems probable that much of this importation could be avoided by the development of the local greensand marl deposits, some of which carry appreciable percentages of phosphoric acid.

## CLAYS AND CLAY INDUSTRIES.

The most important mineral industry of Mississippi is that based on her clay resources. The clay industries are, as yet, not so well developed as the abundant supplies of good clays would justify. This lack of development is due, in part, to lack of published information regarding the variety and extent of the clay deposits of the State, though difficulties in regard to transportation and markets have also retarded the growth of these industries. Recent and prospective improvements in railroads and the steady growth of the villages and cities of this section will doubtless aid greatly in advancing the brick and pottery industries of Mississippi.

According to the statistics collected by the United States Geological Survey, the clay industries of Mississippi during the years 1900 to 1904, inclusive, produced brick and pottery valued as follows:

*Production of pottery and brick in Mississippi, 1900-1904.*

| Year. | Pottery. | Brick. |
|---|---|---|
| 1900 | $14,452 | $558,916 |
| 1901 | 4,779 | 451,694 |
| 1902 | 14,424 | 501,785 |
| 1903 | 14,295 | 658,491 |
| 1904 | 14,701 | 710,878 |

During 1903, according to the statistics gathered in the recent geologic survey of the State, 9 potteries and 86 brick plants were in operation; most of these plants were visited and samples of their clays and product were placed on exhibition at the St. Louis Exposition. In 1904 there were 92 plants reported as engaged in the clay-working industry.

The clays of the State can be described most conveniently under nine headings, according to the geologic groups in which they occur. These are as follows: (1) Clays of the Tuscaloosa formation (lower Cretaceous); (2) Porters Creek clays (lower Eocene); (3) clays of the Wilcox formation (Eocene); (4) clays of the Jackson formation (upper Eocene); (5) clays of the Grand Gulf group (Miocene?); (6) Lafayette clays (Quaternary); (7) loess and yellow-loam clays (Quaternary); (8) Quaternary clays of the Gulf coast; (9) Quaternary clays of the Yazoo delta.

In the description of the clays by formations the general rule will be followed, as far as possible, of naming them by localities from north to south.

### CLAYS OF THE TUSCALOOSA FORMATION (LOWER CRETACEOUS).

The lower portion of the Tuscaloosa formation is largely made up of plastic clays ranging in purity from white kaolin to a common sandy brick clay. They have been used to a small extent in the manufacture of ordinary stoneware and fire brick, and some of the purer clays have been used successfully in making china ware.

They occur in horizontally bedded strata, often immediately overlain by the Lafayette sands. In the northern area of the Tuscaloosa the clays of this group outcrop very frequently along the streams where the thick mantle of Lafayette has been removed. Many of the clays immediately underlying the Lafayette are more or less discolored by iron oxide from the overlying formation.

*Iuka clay.*—At Iuka, Tishomingo County, and for 6 miles north occurs a pink to mottled-purple clay, highly plastic and free from sand. It is found at Lake Como, one-fourth mile east of Iuka, and in numerous branches to the east and north. In some places the clay resembles the bauxite of Arkansas. It has small round spots through it the size of a pea. These spots are much deeper red than the rest of the clay. The analysis given below shows it to be high in alumina and ferric oxide, which gives the clay its pink to red color. A large amount of this clay has been mined and shipped from Iuka for making paint.

*Analysis of Iuka clay, Tishomingo County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 38.11 |
| Alumina ($Al_2O_3$) | 36.42 |
| Ferric oxide ($Fe_2O_3$) | 11.73 |
| Lime (CaO) | .60 |
| Magnesia (MgO) | .14 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | .87 |
| Loss on ignition | 11.96 |
| | 99.83 |

Some of the clay from Lake Como was sent to the Newcomb Pottery in New Orleans and was made into ornamental vases. It was pronounced an excellent clay and the ware made from it shows it to be a product that is worth investigating. The clay burns to a mottled pale red. The larger portion of the clays in the vicinity of Iuka are red to pink in color, but farther south they become whiter.

*Turner clay.*—In sec. 15, T. 4 S., R. 11 E., on the farm of James Turner, two samples of clays, one white and the other pink, were collected in a branch near the house. They are overlain by heavy beds of Lafayette pebbles and sand. At the place of outcrop the branch has cut into the hill, forming a small bluff, in which the clay appears. The pink clay is within 100 feet of the white clay and appears to be a continuation of the same bed. The clays are similar in texture, both free from sand and very plastic. The only apparent difference between them is that the pink clay contains a larger amount of ferric oxide. The following analysis shows the character of the white clay from the Turner place:

*Analysis of Turner clay, Tishomingo County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 66.85 |
| Alumina ($Al_2O_3$) | 20.54 |
| Ferric oxide ($Fe_2O_3$) | 3.77 |
| Lime (CaO) | .21 |
| Magnesia (MgO) | .18 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | .59 |
| Loss on ignition | 8.00 |
| | 100.14 |

Still farther south Crippledeer Creek, which rises near the center of Tishomingo County and flows eastward into Bear Creek, has cut through the Lafayette and the overlapping Tuscaloosa, exposing the older Paleozoic rocks in its lower course. The cross section of the strata along this stream shows the clayey character of the lower Tuscaloosa.

*Pennywinkle clay.*—On Pennywinkle Hill, in sec. 8, T. 4 S., R. 11 E, is a white plastic clay, which is distinctly stratified. It is purest near the base of the outcrop and gradually passes upward into a less pure dark shaly clay. This is in turn overlain by a yellowish-gray sandy clay. At the top of the yellow clay is a thin band of ferruginated sandstone, on which rest the Lafayette sands. At the bottom of the section the white clay contains small rounded quartz pebbles interbedded in the clay. This clay has been used for years for making stoneware. It burns to a light-cream color. The following is an analysis of this clay:

*Analysis of Pennywinkle clay, Tishomingo County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 68.65 |
| Alumina ($Al_2O_3$) | 18.99 |
| Ferric oxide ($Fe_2O_3$) | 2.77 |
| Lime (CaO) | .20 |
| Magnesia (MgO) | .20 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | 1.09 |
| Loss on ignition | 7.34 |
| | 99.24 |

*Coman clay.*—A similar deposit of clay occurs on J. J. Coman's land in sec. 8, T. 4 S., R. 11 E. The analysis is as follows:

*Analysis of Coman clay, Tishomingo County.*

[By J. Blodgett Britton, of Philadelphia, Pa.]

| | |
|---|---|
| Silica ($SiO_2$) | 80.07 |
| Alumina ($Al_2O_3$) | 11.46 |
| Ferric oxide ($Fe_2O_3$) | .57 |
| Lime ($CaO$) | .12 |
| Magnesia ($MgO$) | .37 |
| Water and organic matter | 6.81 |
| Loss | .60 |
| | 100.00 |

On the south side of Little Pennywinkle Creek the Tuscaloosa clay outcrops on the hillside at about the same elevation as the white clay on Pennywinkle Hill. The clay is of a much darker color than the latter and is highly stratified, almost approaching a shale. At the first bench of the hill the Lafayette has been entirely removed, leaving a large outcrop of the Tuscaloosa, which here is almost as black as lignite.

*Paden clay.*—At the spring in front of R. W. Paden's house in sec. 33, T. 5 S., R. 10 E., immediately underlying the conglomerate at the base of the Lafayette a bed of very white Tuscaloosa clay outcrops. This clay is also exposed in a branch 100 yards west of the house and again one-half mile farther west. It appears in all the deep branches which have cut through the Lafayette in the above-mentioned section. This clay is reported to be 30 feet thick. Its outcrop is usually marked by bold springs of pure water, which has filtered through the overlying Lafayette sands and pebbles. Near the surface the clay contains more or less stains from the oxidized waters of the Lafayette. The following is an analysis of this clay:

*Analysis of Paden clay, Tishomingo County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 80.03 |
| Alumina ($Al_2O_3$) | 12.00 |
| Ferric oxide ($Fe_2O_3$) | 1.68 |
| Lime ($CaO$) | .24 |
| Magnesia ($MgO$) | .26 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | .48 |
| Loss on ignition | 4.82 |
| | 99.51 |

*Clingscale clay.*—On Mr. Clingscale's place, in sec. 8, T. 5 S., R. 11 E., Dr. E. W. Hilgard found a pure-white clay which was 30 feet thick. He obtained a specimen, and the following analysis shows it to be more free from magnesia, lime, and iron oxide than the Paden clay.

*Analysis of Clingscale clay, Tishomingo County.*

[By Dr. E. W. Hilgard.]

| | |
|---|---|
| Silica ($SiO_2$) | 90.877 |
| Alumina ($Al_2O_3$) | 2.214 |
| Ferric oxide ($Fe_2O_3$) | .126 |
| Lime ($CaO$) | .140 |
| Magnesia (Mgo) | Trace. |
| Water and organic matter | 6.930 |
| | 100.287 |

*Various clays.*—Near Dennis, on the farm of W. R. Davis, is a white clay interbedded in the Tuscaloosa sands. It contains minute particles of mica and differs from the white clays farther north in that it is less plastic. It is little more than a finely powdered silica, with just a sufficient amount of alumina to bond it. It burns to a cream color.

Clay of the same character occurs along the headwaters of Lick Creek. On M. C. Hill's land, in sec. 17, T. 6 S., R. 10 E., a white to cream-colored clay outcrops along the creek for 2 miles. The clay is very plastic and free from sand and is similar in appearance when raw and also when burned to that on Mr. Paden's land.

The clays of the lower Tuscaloosa are not always so white and free from impurities as those above mentioned, but throughout the State highly plastic clays are frequently present where the Lafayette has been removed from the surface of the lower portion of the Tuscaloosa. The above-mentioned clays, though of exceptional purity and of high economic value, are as yet undeveloped. Farther south, in the lower Tuscaloosa area in Itawamba County, there is less of the white clay, but a large amount of very plastic gray and often pink clays. Many of these clays are dark colored, containing more or less organic matter, but when burned they become cream to pink-buff in color. Their high degree of plasticity renders them valuable for making stoneware.

*Reedsville clay.*—This clay outcrops along the headwaters of Reeds Creek about 6 miles south of Fulton, Itawamba County. There is more or less Lafayette and Tuscaloosa sand on the hills, which are often steep and wooded. The clay occurs near the base of the hills underneath a seam of lignite about 18 inches thick. The following section shows the relation of the clay to the other strata:

*Section on Reeds Creek 6 miles south of Fulton.*

| | Ft. | In. |
|---|---|---|
| 5. Lafayette sands and pebbles | 5–20 | |
| 4. Tuscaloosa sands, very coarse, alternating with thin strata of clay and containing small fragments of woody lignite | 60–80 | |
| 3. Ferruginous sandstone, hard as flint | | 1–3 |
| 2. Black, pure lignite, containing small amount of iron pyrites | | 18 |
| 1. Plastic gray clay, with more or less lignitic material through it | 10 | |
| Bottom of branch. | | |

The lignite horizon is fairly constant throughout this locality. It gives rise to bold springs in many of the valleys. The clay was formerly used for making jug ware, but the plant has been discontinued. The ware burns to a color varying from rich cream to pale yellow.

Bull Mountain Creek and many of its small tributaries, in southeastern Itawamba County, have carried away much of the Lafayette and exposed in numerous places the underlying Tuscaloosa clays. There are three stoneware factories within a radius of 6 miles on the east side of Bull Mountain Creek.

*Davidson clay.*—This clay outcrops in the road near Jim Davidson's house, in sec. 29, T. 10 S., R. 10 E. It occurs in a horizontal stratum 4 feet thick, overlain by Lafayette sand. Numerous leaf impressions are reported from this clay. Between the clay pit and the house is a ledge of soft sandstone at a lower elevation than the clay stratum. Immediately below the sandstone is another stratum of siliceous clay but a few inches thick. The former clay is used at the Davidson pottery for making stoneware. It burns to a cream-buff color.

*Sumerford clay.*—On the farm of W. A. Sumerford, in the SW. ¼, sec. 11, T. 11 S., R. 10 E., the Lafayette has, in places, been entirely removed, leaving a bluish to pink clay at the surface. In the road at Mr. Sumerford's house the clay is exposed for 100 yards. It is horizontally bedded, but its thickness has not been ascertained. This clay is used by Mr. Sumerford for making stoneware, in which process it is necessary to mix the plastic clay which occurs but a foot or two below the surface with the more sandy surface clay. The color, when burned, is very similar to that of the Davidson clay. The analyses of the two clays are given below for comparison:

*Analyses of Davidson and Sumerford clays, Itawamba County.*

[By W. F. Hand, State chemist.]

| | Davidson clay. | Sumerford clay. |
|---|---|---|
| Silica ($SiO_2$) | 59.12 | 62.58 |
| Alumina ($Al_2O_3$) | 27.44 | 27.58 |
| Ferric oxide ($Fe_2O_3$) | 4.39 | 1.57 |
| Lime (CaO) | .34 | .40 |
| Magnesia (MgO) | .28 | Trace. |
| Sulphur trioxide ($SO_3$) | Trace. | Trace. |
| Moisture | .54 | .77 |
| Loss on ignition | 7.40 | 6.77 |

The analyses show the clays to be strikingly similar. The amount of silica and alumina in each is about equal. The Davidson clay contains more iron oxide than the Sumerford, though brick burned from the two clays at the same temperature show a slightly deeper pink for the Davidson clay.

One mile north of the Sumerford pottery E. P. Kennedy has a jug factory. Apparently the same stratum of clay is used at the two places. There is a greater thickness of Lafayette here than overlies the Sumerford clay, and the clay has a greater amount of iron oxide, as the analysis below will show. When burned the clay has a pink-buff color.

*Analysis of clay from Kennedy factory, Itawamba County.*

| | |
|---|---|
| Silica ($SiO_2$) | 71.53 |
| Alumina ($Al_2O_3$) | 14.46 |
| Ferric oxide ($Fe_2O_3$) | 4.14 |
| Lime (CaO) | .62 |
| Magnesia (MgO) | .55 |
| Moisture | 2.17 |
| Loss on ignition | 5.91 |

### PORTERS CREEK CLAYS (LOWER EOCENE).

The clays of this formation underlie the well-known "Flatwoods" lying west of the Ripley area in northern Mississippi and west of the Selma chalk area south of Houston, Chickasaw County. The clays embrace the upper division of the series shown on the map as Midway. North of Pontotoc the clays are underlain by 20 feet or more of calcareous sands and this, in turn, by about the same thickness of Turritella limestone. South of Pontotoc, however, the sands and limestone have not been found if present and the entire Midway is composed of the Porters Creek clays.

There is a remarkable similarity in these clays throughout the State. When wet they are very stiff, of a gray or black color, but when dry they become a light gray to white.

The entire "Flatwoods" area throughout the State has always been regarded as very poor agricultural land. The clayey soil is very poor in lime, phosphate, and other ingredients necessary to constitute fertility. The following analysis of the Porters Creek or Flatwoods clay soil was made by Dr. E. W. Hilgard:[a]

*Analysis of Porters Creek clay soil.*

| | |
|---|---|
| Silica ($SiO_2$) | 77.854 |
| Alumina ($Al_2O_3$) | 10.302 |
| Ferric oxide ($Fe_2O_3$) | 5.899 |
| Lime (CaO) | .178 |
| Magnesia (MgO) | .831 |
| Potash ($K_2O$) | .753 |

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[a] Geology and Agriculture of Mississippi, 1860, p. 276.

| | |
|---|---|
| Soda ($Na_2O$) | .106 |
| Brown oxide of Manganese | .167 |
| Phosphoric acid | .052 |
| Sulphuric acid | .032 |
| Organic matter and water | 3.689 |
| | 99.863 |

The Porters Creek clay comes to the surface along the Mobile, Jackson and Kansas City Railroad and on the hillsides and streams in Tippah County. At almost every place where it is seen it has a strikingly similar appearance, so that it can readily be distinguished from the Lafayette or Wilcox, lying farther to the west. It outcrops on the railroad one-half mile north of Walnut, Tippah County, at the water tank, and again one-half mile north of the tank. At each of these places it occurs in horizontal strata. It is very plastic, of a leaden-gray color, with a slight pink tinge. It is free from sand and does not effervesce with acid. Farther west it is reported to have a slight amount of calcareous matter through it. The same clay occurs in the hills 2½ to 3 miles southwest of Walnut, with a coarse-grained fossiliferous sandstone capping the tops of the hills.

The relation of the Porters Creek clay to the other strata in the vicinity of Walnut is given in the generalized section below:

*Generalized section near Walnut.*

| | Ft. | In. |
|---|---|---|
| 6. Gray fossiliferous sandstone capping tops of hills | 50–75 | |
| 5. Leaden-gray nonfossiliferous joint clay, as seen along railroad north of Walnut and in hills 2½ miles southwest | 50–75 | |
| 4. Greenish band of calcareous sandstone, as seen at Chalybeate | | 8–26 |
| 3. Yellowish calcareous sand, with slight amount of greensand present at Chalybeate and on Bobo place, east of Walnut | 30–40 | |
| 2. Turritella limestone rock, as seen at Chalybeate and vicinity | 5–15 | |
| 1. "Owl Creek" marl, as seen at Chalybeate and farther south | 10 | |

The "Owl Creek" marl bed belongs to the uppermost horizon of the Cretaceous. All the strata above belong to the Tertiary. The same order of strata is present at Ripley.

As above stated, the Turritella limestone lying below and the fossiliferous sandstone above the Porters Creek clays have not been found in southern Mississippi. At Scooba, Kemper County, the heavy Flatwoods or Porters Creek clays are very common. The "Flatwoods" belt here is about 10 miles wide and the entire area is underlain by gray plastic clay. The following analysis of a sample of the clay from Scooba was made in the laboratory of the United States Geological Survey:

*Analysis of Porters Creek clay from Scooba, Kemper County.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 61.92 |
| Alumina ($Al_2O_3$) | 19.47 |
| Ferric oxide ($Fe_2O_3$) | 2.81 |
| Magnesia (MgO) | 1.98 |
| Soda ($Na_2O$) | .50 |
| Loss on ignition | 12.29 |
| | 98.97 |

## WILCOX CLAYS (EOCENE).

The clays of the Wilcox formation comprise a large assortment, from the coarse sandy clays, well adapted for making lime-sand brick, to the white pottery clays as found at Holly Springs and Oxford. They occur more or less generally throughout the formation, but those which have so far been developed and used to any extent are found outcropping in a comparatively narrow belt that extends in a general north-south direction near the center of the Wilcox area. The outcrop of the clays is marked by a series of stoneware factories. This belt, from 3 to 10 miles wide, can be traced into Tennessee, and from the Tennessee line southward it passes through northwestern Benton, eastern Marshall, central Lafayette, western Calhoun, central Webster, eastern Choctaw, and central Winston counties. Farther south there has been no detailed work to determine whether or not the clays are present.

There is a great similarity in the clays from the Tennessee line to Calhoun County. Forty-five samples were collected from Benton, Marshall, and Lafayette counties. When made into small bricks and burned to the same temperature they show a striking similarity. In color they range from almost pure white to a light chocolate, with all of the intermediate shades.

The clays of this formation may be divided into two distinct groups—stratified and unstratified clays.

### STRATIFIED CLAYS.

The class of stratified clays includes the more arenaceous clays which occur in horizontal strata interbedded with the coarse, laminated sands of the Wilcox. In places the clays are remarkably free from impurities and could be used for various economic purposes. In some places they are being made into common stoneware, such as jugs, crockery, and churns.

The greater part of the stratified clays contain too much free sand for stoneware and pottery, but could be used advantageously for making a high grade of white to buff-colored pressed brick, fire brick, lime-sand brick and pavers, terra cotta, and tiling.

### UNSTRATIFIED CLAYS.

The high-class white pottery clays found particularly in the northern counties occur in large lens-shaped bodies. They are comparatively free from sand and other impurities. The potteries of Holly Springs obtain their clay from these unstratified bodies. Fossil leaf impressions have been found throughout the clays.

The composition of these clays, as shown by the analyses below, is such that they can be used for making low-grade pottery and in some instances a finer grade of ware. They could also be used for making gas retorts, crucibles, and fire brick.

### NOTES ON WILCOX CLAYS.

*Brown clay.*—In sec. 25, T. 1, R. 2 E., near Laird, Benton County, clay occurs in laminated sands of the Wilcox, from which the Lafayette has been removed. It is plastic, free from sand, and burns to a cream-white color. Numerous other outcrops occur in the gullies near by. An analysis of this clay is given below:

*Analysis of Brown clay, Benton County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 55.87 |
| Alumina ($Al_2O_3$) | 30.19 |
| Ferric oxide ($Fe_2O_3$) | 2.44 |
| Lime (CaO) | .53 |
| Magnesia (MgO) | .24 |
| Sulphur trioxide ($SO_3$) | .23 |
| Moisture | 1.12 |
| Loss on ignition | 9.22 |
| | 99.84 |

*Maclin clay.*—In sec. 28, T. 1 S., R. 2 E., Benton County, on J. Maclin's land, clay occurs in a deeply washed gully at the top of Wilcox sands. It is overlain by the Lafayette sands. The raw clay has a slightly bluish color, but burns to a cream-white. It is high in alumina and therefore very plastic. In almost every large gully where the overlying Lafayette has been removed the white Wilcox clays are present. The thickness of the deposits is undetermined. An analysis of the Maclin clay is given below:

*Analysis of Maclin clay, Benton County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 64.86 |
| Alumina ($Al_2O_3$) | 20.70 |
| Ferric oxide ($Fe_2O_3$) | 4.19 |
| Lime (CaO) | .69 |
| Magnesia (MgO) | .59 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | .62 |
| Loss on ignition | 7.02 |
| | 98.67 |

*Parham clay.*—A very fat white clay occurs in the NW. ¼ sec. 36, T. 1 S., R. 1 E., Benton County. It is free from sand and burns to a rich cream color. It occurs in a large lens-shaped body, 4 feet thick, and is uncovered for 100 yeards along a branch. When dry the clay has a tendency to break up into large rectangular blocks. Fossil leaf impressions are abundant. This clay has been used by the Grand Junction Pottery Company and found to be excellent for making common stoneware. Below is an analysis of the Parham clay:

*Analysis of Parham clay, Benton County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 59.02 |
| Alumina ($Al_2O_3$) | 25.78 |
| Ferric oxide ($Fe_2O_3$) | 3.25 |
| Lime (CaO) | .47 |
| Magnesia (MgO) | .24 |
| Sulphur trioxide ($SO_3$) | .42 |
| Moisture | 1.09 |
| Loss on ignition | 8.37 |
| | 98.64 |

*Umbarger clay.*—In sec. 2, T. 2 S., R. 2 E., a yellow, lean, sandy clay occurs in the stratified Wilcox sands. The clay here is entirely below the Lafayette and is made up of thin laminæ of clays intermingled with more or less fine sand. It burns to a rich buff color. As in the other places mentioned above the clay is present in a large number of gullies where the surface soil and Lafayette have been washed away. An analysis of this clay is given below:

*Analysis of Umbarger clay, Benton County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 75.78 |
| Alumina ($Al_2O_3$) | 14.11 |
| Ferric oxide ($Fe_2O_3$) | 3.56 |
| Lime (CaO) | .54 |
| Magnesia (MgO) | .52 |
| Moisture | .23 |
| Loss on ignition | 4.81 |
| | 99.55 |

*Boughton clay.*—A gray clay with pink streaks through it occurs in the Wilcox strata in the NW. ¼ sec. 34, T. 1 S., R. 2 E., Benton County. It is free from sand and highly plastic. The following is an analysis of this clay:

*Analysis of Boughton clay, Benton County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 56.32 |
| Alumina ($Al_2O_3$) | 28.60 |
| Ferric oxide ($Fe_2O_3$) | 2.60 |
| Lime (CaO) | .45 |
| Magnesia (MgO) | .20 |
| Sulphur trioxide ($SO_3$) | .32 |
| Moisture | .98 |
| Loss on ignition | 8.89 |
| | 98.38 |

*Poorhouse clay.*—Clay occurs in a large branch on the public road in front of the poorhouse in sec. 26, T. 3 S., R. 3 W., Marshall County. The Lafayette is present on the hillside and has washed down to and overlies the clay bed. The clay occurs in a large lens, with a thickness of 10 feet exposed. The entire thickness has not been determined, as it is undeveloped. This clay has been tested by A. Herr, manager of the Holly Springs Stoneware and Fire-Brick Company, and he found it to be an excellent clay for making stoneware. It is of a leaden-gray color when damp and burns to a rich cream or white. The following is an analysis of the Poorhouse clay:

*Analysis of Poorhouse clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 61.31 |
| Alumina ($Al_2O_3$) | 24.44 |
| Ferric oxide ($Fe_2O_3$) | 2.77 |
| Lime (CaO) | .57 |
| Magnesia (MgO) | .29 |
| Sulphur trioxide ($SO_3$) | .23 |
| Moisture | 1.78 |
| Loss on ignition | 8.11 |
| | 99.50 |

*McDowell clay.*—In the Illinois Central Railroad cut, one-half mile south of Mahon station, in sec. 25, T. 3 S., R. 3 W., occurs a highly siliceous, lean, nonplastic clay containing small particles of mica, several feet below the base of the Lafayette. This clay burns to a light-cream color.

The following section shows the relation of the clay to the stratified Wilcox and the overlying Lafayette and surface loam:

*Section in Illinois Central Railroad cut one-half mile south of Mahon station.*

| | Feet. |
|---|---|
| 4. Yellow (Columbia) loess loam | 8 |
| 3. Lafayette, unstratified | 2½ |
| 2. Irregularly bedded yellow and white sharp-grained sand | 10 |
| 1. Red coarse-grained sand with thin bands of ferruginous sandstone. This bed is more irregularly bedded than the one above and the sand grains are much larger. The clay occurs in this bed of coarse sand in a long lenticular mass, which grades into a clayey sand. Thickness of the clay, 10 feet | 15 |

The following is an analysis of the McDowell clay:

*Analysis of McDowell clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 77.64 |
| Alumina ($Al_2O_3$) | 12.33 |
| Ferric oxide ($Fe_2O_3$) | 3.10 |
| Lime (CaO) | .51 |
| Magnesia (MgO) | .12 |
| Sulphur trioxide ($SO_3$) | .54 |
| Moisture | .44 |
| Loss on ignition | 4.65 |
| | 99.33 |

A few hundred yards south of the above-mentioned clay a more plastic clay outcrops on each side of the railroad track. It has a bluish tinge when fresh and damp and burns to a very light cream color, almost white. No analysis of this clay has been made.

*Fant clay.*—Highly colored white, pink, and gray clays, many of them free from sand, are present in numerous gullies and along the streams in sec. 9, T. 3 S., R. 3 W., on the farm of Ernest Fant. They occur in lenticular masses embedded in the sand. In some places the Lafayette rests directly on the clay, in others the clay is entirely in the highly stratified variegated sands. The following is an analysis of the Fant clay:

*Analysis of Fant clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 70.86 |
| Alumina ($Al_2O_3$) | 15.68 |
| Ferric oxide ($Fe_2O_3$) | 4.50 |
| Lime (CaO) | .45 |
| Magnesia (MgO) | .79 |
| Sulphur trioxide ($SO_3$) | .29 |
| Moisture | .83 |
| Loss on ignition | 6.12 |
| | 99.52 |

*Terr clay.*—On Home Terr's land, in sec. 35, T. 2. S, R. 3 W., the stratified character of the Wilcox sands and clays is well shown in the section along the creek near the old water mill. A small side stream entering the creek at the mill has cut through the Lafayette and into the alternating beds of sands and clays beneath. At the base of the section is a yellow plastic clay from which a sample was taken. When made into a brick and burned it becomes of a rich buff color. The following section gives the relation of the different strata:

*Section on Terr place, in sec. 35, T. 2 S., R. 3 W.*

| | Inches. |
|---|---|
| 7. Lafayette | 72 |
| 6. Coarse micaceous sand, chocolate colored | 6 |
| 5. Yellow sand | 6 |
| 4. Yellow sand alternating with white clay one-fourth to 1 inch thick | 5 |
| 3. White joint clay, micaceous | 8 |
| 2. Yellow micaceous sand | 48 |
| 1. Yellow clay from which sample was taken; bottom of branch | 24 |

The following is the analysis of the Terr clay:

*Analysis of Terr clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 63.56 |
| Alumina ($Al_2O_3$) | 21.92 |
| Ferric oxide ($Fe_2O_3$) | 2.83 |
| Lime (CaO) | .48 |
| Magnesia (MgO) | .62 |
| Sulphur trioxide ($SO_3$) | .28 |
| Moisture | 1.92 |
| Loss on ignition | 7.66 |
| | 99.27 |

*Ballard clay.*—In the old field surrounding the negro schoolhouse in sec. 30, T. 2 S., R. 2 W., are numerous deep gullies. In many of these plastic, workable clays are exposed.

At the bold spring near the schoolhouse is a small bluff showing 20 feet of coarse, orange-colored sand, with small streaks and lenses of clay throughout. At the base of the bluff is a large outcrop of very plastic white to pinkish clay which has given rise to the spring. The water filters down through the sand until it reaches the clay. On the opposite side of the schoolhouse from the spring is an outcrop of stratified clay in a gully. When exposed to the sun and air this clay, known as the Ballard clay, cracks into roughly rectangular blocks, as does the Parham clay. Like the Parham clay also it contains numerous fossil leaf impressions. The clay is white, contains but little sand, and burns almost white. An analysis of this clay is given below:

*Analysis of Ballard clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 63.95 |
| Alumina ($Al_2O_3$) | 21.42 |
| Ferric oxide ($Fe_2O_3$) | 3.88 |
| Lime (CaO) | .39 |
| Magnesia (MgO) | .73 |
| Sulphur trioxide ($SO_3$) | .29 |
| Moisture | 1.74 |
| Loss on ignition | 7.39 |
| | 99.79 |

*Red Bank clay.*—One of the best localities for studying the lenticular character of the Wilcox is in the high divide between the waters of Chewalla Creek on the north and Red Bank Creek on the south, in the vicinity of Red Bank station, in sec. 16, T. 3 S., R. 4 W. About one-half mile south of the station is a large abandoned field from which the Lafayette has been mostly eroded. In places the gullies are washed out 20 feet deep and the whole field is fantastically carved into miniature landscapes. The Wilcox here contains numerous lenses of white, gray, and pink clays, many of which are highly plastic and free from sand. In places the gullies are deep enough to show the full thickness of the clay deposits—not more than 3 to 4 feet on an average. A sample of clay was taken from a large lenticular body on the roadside one-fourth mile south of the church. It burned to a buff color and is flecked with small brown to reddish spots. Below is an analysis of the Red Bank clay.

*Analysis of Red Bank clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 65.88 |
| Alumina ($Al_2O_3$) | 21.19 |
| Ferric oxide ($Fe_2O_3$) | 2.89 |
| Lime (CaO) | .72 |
| Magnesia (MgO) | .15 |
| Sulphur trioxide ($SO_3$) | .30 |
| Moisture | 1.23 |
| Loss on ignition | 7.02 |
| | 99.38 |

*Hern clay.*—This deposit occurs on the roadside about 3½ miles north of Holly Springs and about one-half mile north of the old pit from which the Holly Springs Stoneware and Fire-Brick Company formerly obtained clay for making stoneware. The Hern clay occurs in stratified layers with sand partings. It has a bluish tint, is very plastic, and burns to a buff color very similar to that of the Red Bank clay. Its relation to the Lafayette is shown in the section below.

*Section 3½ miles north of Holly Springs.*

| | Feet. |
|---|---|
| 4. Lafayette sands with ferruginous sandstone at base | 10-12 |
| 3. Stratified plastic clay of a bluish tint, in places containing a small amount of sand | 3 |
| 2. Gray laminated clay 1 to 4 inches thick, alternating with layers of gray sand of about equal thickness | 4 |
| 1. Yellowish laminated sand and clay containing nodules of iron oxide | 5 |

This clay has been analyzed with the following results:

*Analysis of Hern clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 60.78 |
| Alumina ($Al_2O_3$) | 24.12 |
| Ferric oxide ($Fe_2O_3$) | 3.52 |
| Lime (CaO) | .73 |
| Magnesia (MgO) | .38 |
| Sulphur trioxide ($SO_3$) | .38 |
| Moisture | 1.84 |
| Loss on ignition | 8.25 |
| | 100.00 |

*Holly Springs clay.*—The clay deposit at Holly Springs is in a large branch on the west side of the Illinois Central Railroad, about one-fourth mile north of the depot. The clay is a bluish gray with yellow horizontal streaks through it, giving it a laminated appearance. A small amount of gray sand is embedded in the clay. The deposit is not continuous for more than 25 feet and is 4½ feet thick. It is overlain by 10 feet of deep Indian-red Lafayette. An interesting feature of this deposit is the large number of small lenses of highly plastic clay in the sand around the large deposit. Some of these small bodies are 2 feet long and from 1 to 2 inches thick. They are not very far distant from the larger mass and are entirely wanting in the Lafayette. The following is an analysis of this clay:

*Analysis of Holly Springs clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 67.02 |
| Alumina ($Al_2O_3$) | 20.89 |
| Ferric oxide ($Fe_2O_3$) | 2.93 |
| Lime (CaO) | .67 |
| Magnesia (MgO) | .55 |
| Sulphur trioxide ($SO_3$) | .49 |
| Moisture | .96 |
| Loss on ignition | 6.70 |
| | 100.21 |

*Dunlap clay.*—A clay deposit occurs on Joe Dunlap's land in the cut where the Holly Springs and Pontotoc road crosses the Frisco Railroad. The clay is horizontally bedded and is exposed for a distance of 350 feet along the cut, with a thickness of 2 feet showing above the surface. It is a tough, white, siliceous clay, flecked with small particles of mica and burns to a cream-white. It is overlain by 6 to 7 feet of micaceous clayey sand. The top of the hill is covered with 6 to 7 feet of yellow loam. The following analysis has been made of the Dunlap clay:

*Analysis of Dunlap clay, Marshall County.*

[By W. F. Hand, State Chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 62.41 |
| Alumina ($Al_2O_3$) | 24.02 |
| Ferric oxide ($Fe_2O_3$) | 2.80 |
| Lime (CaO) | .57 |
| Magnesia (MgO) | .50 |
| Sulphur trioxide ($SO_3$) | .56 |
| Moisture | .66 |
| Loss on ignition | 7.25 |
| | 98.77 |

*Holly Springs stoneware clay.*—One and one-half miles east of the Holly Springs depot is a small area comprising 20 or 30 acres from which the Holly Springs Stoneware Company gets the clay for making its ware. The clay occurs in large lenticular masses with a maximum length of 80 feet. Perhaps 25 yards from the point where one of these lenses cuts out, another large lens, or "mountain," as the clay digger calls it, will begin. The greatest thickness of the clay so far penetrated is 18 feet, and the bottom was not then reached. One pit is used until it gets too deep to throw the clay out with a shovel or until a rain fills it with water, and it is then abandoned and another opened. Small deposits of pure sand, from 1 inch to 1 foot thick and 2 to 3 feet long, often occur in the center of the clay lenses. The digger reports that numerous leaf impressions are found at a depth of 10 to 12 feet. Clay coming from a depth of 10 feet works better than that near the surface. This clay is very plastic, free from sand, and has to be mixed with a more sandy clay before it is made into stoneware. It burns to a cream color under high heat. The following is an analysis of this clay:

*Analysis of Holly Springs stoneware clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 67.70 |
| Alumina ($Al_2O_3$) | 19.69 |
| Ferric oxide ($Fe_2O_3$) | 3.04 |
| Lime ($CaO$) | 1.06 |
| Magnesia ($MgO$) | .58 |
| Sulphur trioxide ($SO_3$) | .19 |
| Moisture | .94 |
| Loss on ignition | 6.64 |
| | 99.84 |

*Allison stoneware clay.*—The clay used by the Allison pottery comes from a pit along the same branch as the Holly Springs stoneware-clay pit. The Allison clay differs from the other clay in being stratified instead of occurring in lenses. At the top of the pit are 4 to 5 feet of Lafayette, below which are 10 feet of clay. The upper half of the clay is more arenaceous than the lower and has a pinkish color. The lower half is a white plastic clay which is used for making stoneware. Immediately below the white clay is a thin band of lignite, and this in turn is underlain by 4 to 5 feet of variegated sands. A glance at the sands shows white, black, red, orange, yellow, and blue colors. The following analysis shows the composition of the Allison clay:

*Analysis of Allison stoneware clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 61.69 |
| Alumina ($Al_2O_3$) | 24.91 |
| Ferric oxide ($Fe_2O_3$) | 2.04 |
| Lime ($CaO$) | .34 |
| Magnesia ($MgO$) | .83 |
| Sulphur trioxide ($SO_3$) | .20 |
| Moisture | 1.51 |
| Loss on ignition | 8.07 |
| | 99.59 |

*Frisco fire clay.*—About 100 yards east of the Frisco depot at Holly Springs is a deposit of white sandy clay which is made into fire brick and used in lining the kilns of the Holly Springs Stoneware Company. The bricks stand the highest degree of heat required in burning the ware without going to pieces. In appearance the clay is little more than a mass of slightly bonded sand which occurs at the surface in large bodies and is distinct in color from the loose variegated sands in the vicinity. The following is an analysis of this clay:

*Analysis of Frisco fire clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 88.52 |
| Alumina ($Al_2O_3$) | 5.26 |
| Ferric oxide ($Fe_2O_3$) | 1.64 |
| Lime ($CaO$) | .73 |
| Magnesia ($MgO$) | .13 |
| Sulphur trioxide ($SO_3$) | .43 |
| Moisture | .87 |
| Loss on ignition | 1.93 |
| | 99.51 |

A clay very similar to the one above mentioned, as is shown by the analysis given below, occurs just south of the Frisco depot:

*Analysis of Frisco fire clay No. 2, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 84.40 |
| Alumina ($Al_2O_3$) | 6.79 |
| Ferric oxide ($Fe_2O_3$) | 1.30 |
| Lime ($CaO$) | .85 |
| Magnesia ($MgO$) | .27 |
| Sulphur trioxide ($SO_3$) | .17 |
| Moisture | .74 |
| Loss on ignition | 5.36 |
| | 99.88 |

*Whitelock clay.*—The Whitelock clay outcrops at the spring where the Illinois Central Railroad crosses the public road, 2 miles south of Holly Springs. It is a white plastic clay flecked with mica, and occurs in stratified sands 40 feet below the base of the Lafayette. It burns to a cream color. An analysis of this clay is given below:

*Analysis of Whitelock clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 66.66 |
| Alumina ($Al_2O_3$) | 22.29 |
| Ferric oxide ($Fe_2O_3$) | 1.57 |
| Lime ($CaO$) | .62 |
| Magnesia ($MgO$) | .28 |
| Sulphur trioxide ($SO_3$) | .11 |
| Moisture | 1.23 |
| Loss on ignition | 2.41 |
| | 95.17 |

*Wyley clay.*—A very white nonplastic clay occurs in stratified layers near the house of Sid. Wyley, in sec. 16, T. 8 S., R. 4 W., Lafayette County. The following section was taken from the gully in which the clay outcrops:

*Section on Wyley place, in sec. 16, T. 8 S., R. 4 W.*

| | Feet. |
|---|---|
| 5. Yellow loam and Lafayette at surface. | |
| 4. Impure sandy clay | 2 |
| 3. White plastic clay from which sample was taken | 10 |
| 2. Impure yellow clay | 1½ |
| 1. Whitish-gray sand to bottom of gully | 2 |

At the base of the yellow clay is a thin band of ferruginous sandstone and numerous concretions of iron clay stones. The following analysis has been made of this clay:

*Analysis of Wyley clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 57.48 |
| Alumina ($Al_2O_3$) | 26.94 |
| Ferric oxide ($Fe_2O_3$) | 2.43 |
| Lime ($CaO$) | .78 |
| Magnesia ($MgO$) | .27 |
| Sulphur trioxide ($SO_3$) | .20 |
| Moisture | 1.64 |
| Loss on ignition | 8.99 |
| | 98.73 |

*Callicoatt clay.*—An outcrop of clay occurs near C. C. Callicoatt's house, in sec. 16, T. 9 S., R. 3 W. This clay is slightly yellowish, free from sand, and burns to a rich cream color. There is an old Indian pottery near by, with numerous pieces of pottery which were made from this clay bank. The following is an analysis of the Callicoatt clay:

*Analysis of Callicoatt clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 68.75 |
| Alumina ($Al_2O_3$) | 19.57 |
| Ferric oxide ($Fe_2O_3$) | 1.68 |
| Lime (CaO) | .56 |
| Magnesia (MgO) | .19 |
| Sulphur trioxide ($SO_3$) | .13 |
| Moisture | .90 |
| Loss on ignition | 6.17 |
| | 97.95 |

*Moss clay.*—This clay outcrops in a deep gully on the public road just in front of a negro cabin on Robert Moss's land. The Lafayette rests directly on the clay, which occurs in a lenticular mass in the variegated sands of the Wilcox formation. The clay is free from grit, very fat, and has a pinkish tinge. The thickness of the deposit is at least 10 feet. Below is an analysis of the Moss clay:

*Analysis of Moss clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 70.56 |
| Alumina ($Al_2O_3$) | 19.03 |
| Ferric oxide ($Fe_2O_3$) | 2.27 |
| Lime (CaO) | .49 |
| Magnesia (MgO) | .13 |
| Sulphur trioxide ($SO_3$) | .19 |
| Moisture | .63 |
| Loss on ignition | 6.66 |
| | 99.96 |

*Miller clay.*—In the vicinity of George Miller's house, in sec. 8, T. 8 S., R. 3 W., are large bodies of very lean, nonplastic soapstone or clay which often cover an acre or more. The clay is almost snow white and, where the Lafayette has been removed, can be seen for a long distance before reaching the outcrop. These deposits occur in horizontal laminæ one-fourth inch to 2 inches thick. More or less mica is present throughout, with a large amount of highly siliceous material. This clay has been analyzed with the following results:

*Analysis of Miller clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 85.78 |
| Alumina ($Al_2O_3$) | 6.68 |
| Ferric oxide ($Fe_2O_3$) | 1.30 |
| Lime (CaO) | .48 |
| Magnesia (MgO) | .14 |
| Sulphur trioxide ($SO_3$) | .32 |
| Moisture | .73 |
| Loss on ignition | 2.37 |
| | 97.80 |

*Oxford clay.*—A sample of clay was obtained from the deep gully near the colored-school building in the town of Oxford. On all sides of the town the variegated coarse sands of the Wilcox appear in the gullies and along the roads and railroad. The sand is highly cross-bedded. The sample of clay was taken in this cross-bedded sand at the base of the Lafayette. The clay is plastic, free from grit, and burns to a white color. The following is an analysis of this clay:

*Analysis of Oxford clay, Lafayette county.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 57.79 |
| Alumina ($Al_2O_3$) | 26.03 |
| Ferric oxide ($Fe_2O_3$) | 2.98 |
| Lime ($CaO$) | .44 |
| Magnesia ($MgO$) | .10 |
| Sulphur trioxide ($SO_3$) | .24 |
| Moisture | 1.14 |
| Loss on ignition | 9.11 |
| | 97.83 |

*Russell clay.*—A stratified plastic gray clay outcrops in a deep gully on Walsh Russell's land, in Lafayette County, and has been analyzed as follows:

*Analysis of Russell clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 51.88 |
| Alumina ($Al_2O_3$) | 30.64 |
| Ferric oxide ($Fe_2O_3$) | 3.53 |
| Lime ($CaO$) | .58 |
| Magnesia ($MgO$) | .60 |
| Moisture | 1.16 |
| Loss on ignition | 10.14 |
| | 98.53 |

*Grenada clay No. 1.*—At the wagon bridge across Yalobusha River at Grenada the dark-blue lignitic clay of the upper Wilcox formation outcrops in the river bank, where there is an exposure of this clay 20 feet thick. It is overlain by more sandy clays, which alternate with strata of micaceous sand to the top of the high hill west of Grenada. There is more or less fine siliceous sand and mica in the dark clay at the bridge. When burned the clay becomes a pale rusty red, owing to the presence of iron oxide. The following is an analysis of this clay:

*Analysis of Grenada clay No. 1, Grenada County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 61.80 |
| Alumina ($Al_2O_3$) | 16.50 |
| Ferric oxide ($Fe_2O_3$) | 3.88 |
| Lime ($CaO$) | 1.00 |
| Magnesia ($MgO$) | .23 |
| Sulphur trioxide ($SO_3$) | .19 |
| Moisture | 5.91 |
| Loss on ignition | 8.75 |
| | 98.26 |

*Grenada clay No. 2.*—At the foot of the high range of hills 1 mile east of Grenada, on the public road, is a very siliceous clay belonging to the Wilcox formation. This has been analyzed as follows:

*Analysis of Grenada clay No. 2, Grenada County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 90.33 |
| Alumina ($Al_2O_3$) | 2.85 |
| Ferric oxide ($Fe_2O_3$) | 1.49 |
| Lime ($CaO$) | .71 |
| Magnesia ($MgO$) | .14 |
| Sulphur trioxide ($SO_3$) | .19 |
| Moisture | .58 |
| Loss on ignition | 1.45 |
| | 97.74 |

*Winston County stoneware clay.*—On the old Eiland place, in sec. 16, T. 15 N., R. 13 W., Winston County, in a deep gully along the public road, is an outcrop of clay, which is being used by the Webster and Joplin stoneware potteries for making common stoneware. The clay is pink with streaks of white, resembling castile soap. Like the Parham clay, when air dried, it breaks up into more or less rectangular blocks. It occurs in a lenticular mass 2½ feet thick in the bed of clayey, indurated sand containing mica. The clay burns to a rich buff color. The following analysis has been made of this clay:

*Analysis of Winston County stoneware clay.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 57.37 |
| Alumina ($Al_2O_3$) | 29.87 |
| Ferric oxide ($Fe_2O_3$) | 1.88 |
| Lime ($CaO$) | .71 |
| Magnesia ($MgO$) | .14 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | .81 |
| Loss on ignition | 8.53 |
| | 99.31 |

*Webster County stoneware clay.*—At Cumberland, Webster County, is a small stoneware factory, which secures its clay from a pit on the side of the public road on land belonging to B. F. Sanders, in sec. 22, T. 20 N., R. 11 W. The clay has a chocolate color, due to the carbonaceous matter, and does not require the admixture of other clays for making stoneware. It burns to almost a snow white. It occurs in stratified planes overlain by a less pure sandy clay. The following is an analysis of this clay:

*Analysis of Webster County stoneware clay.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 59.82 |
| Alumina ($Al_2O_3$) | 27.19 |
| Ferric oxide ($Fe_2O_3$) | 1.26 |
| Lime ($CaO$) | .49 |
| Magnesia ($MgO$) | .37 |
| Sulphur trioxide ($SO_3$) | .31 |
| Moisture | 1.47 |
| Loss on ignition | 9.24 |
| | 100.15 |

### CLAYS OF THE JACKSON FORMATION (UPPER EOCENE).

Very little attention has been paid to the vast deposits of calcareous clays of the Jackson formation. The importance of these clays from an economic standpoint is yet to be determined. Some of them contain a large amount of lime carbonate, but clay with as high as 20 per cent of lime, if this is in a finely disseminated condition, can be used in making common brick, roof tiling, and in some cases stoneware and terra cotta.

The following analyses and notes on the Jackson clays were made by Dr. E. W. Hilgard:[a]

Underclay of gypseous prairie, from sec. 12, T. 6, R. 3 E. Depth, 3 to 7 feet (as far as visible) below the surface. A greenish-gray heavy clay with numerous small white specks (of gypsum) and some round concretions of iron ore.

*Analysis of clay from sec. 12, T. 6, R. 4 E.*

| | |
|---|---|
| Silica ($SiO_2$) | 67.027 |
| Alumina ($Al_2O_3$) | 10.751 |
| Ferric oxide ($Fe_2O_3$) | 4.344 |
| Lime ($CaO$) | 5.695 |
| Magnesia ($MgO$) | 1.233 |

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[a] Geology and Agriculture of Mississippi, 1860, pp. 337, 340-341.

| | |
|---|---|
| Potash ($K_2O$) | .518 |
| Soda ($Na_2O$) | .41 |
| Brown oxide of manganese (MnO) | .509 |
| Sulphuric acid | 5.751 |
| Carbonic acid | 1.018 |
| Organic matter and water | 2.740 |
| | 100.000 |

Leaf River prairie soil, taken at the crossing of the Paulding and Brandon roads in T. 4 N., R. 8 E., depth 12 inches,-a very clayey soil, almost jet black, crumbling readily on exposure after wetting:

*Analysis of clay from T. 4 N., R. 8 E.*

| | |
|---|---|
| Silica ($SiO_2$) | 63.435 |
| Alumina ($Al_2O_3$) | 16.127 |
| Ferric oxide ($Fe_2O_3$) | 6.996 |
| Lime (CaO) | 1.815 |
| Magnesia (MgO) | 1.112 |
| Potash ($K_2O$) | .796 |
| Soda ($Na_2O$) | .127 |
| Brown oxide of manganese (MnO) | .479 |
| Phosphoric acid | .232 |
| Sulphuric acid | .085 |
| Organic matter, water, and loss | 9.028 |
| | 100.232 |

The above analyses were made from material near the surface, which may properly be considered subsoil. However, they show the character of the underclays of the Jackson formation.

### CLAYS OF THE GRAND GULF GROUP (MIOCENE).

In the Grand Gulf group there are two classes of clays, which have been described under the head of "Grand Gulf group," (pp. 40–44). They are the white siliceous clays interbedded with the siliceous and aluminous sandstone of the northwestern district and the more lignitic plastic clays of the southeastern district. The entire Grand Gulf formation contains more or less clays, all of which occur in stratified beds. In places these beds reach a great thickness.

*Stonington fire clay.*—At Stonington, Jefferson County, occurs a large deposit of white plastic clay, which, by mixing with a more sandy clay, has been used for making pressed brick. When used alone the white clay makes a durable fire brick. The updraft kilns of the brick plant at Stonington are lined with fire brick made from this clay. It is highly plastic and burns to a cream color. The following is an analysis of this clay:

*Analysis of Stonington fire clay, Jefferson County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 78.17 |
| Alumina ($Al_2O_3$) | 13.23 |
| Ferric oxide ($Fe_2O_3$) | 1.73 |
| Lime (CaO) | .28 |
| Magnesia (MgO) | .56 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | 1.24 |
| Loss on ignition | 4.08 |
| | 99.29 |

*Vicksburg clay.*—Five miles south of Vicksburg, on the old Roche land, a thin stratum of friable sandstone outcrops about 40 feet above the bed of the branch. Below the sandstone appears a bed of white friable clay which is derived from the decomposition of the sandstone. Some of the fragments show the sandstone in the process of change. It is very rotten and can be crumbled between the fingers. The sandstone belongs to the Grand Gulf formation. It is underlain by calcareous beds. The thickness of the clay bed could not be determined. The following analysis shows the composition of this clay:

*Analysis of Vicksburg clay, Warren County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 58.50 |
| Alumina ($Al_2O_3$) | 19.04 |
| Ferric oxide ($Fe_2O_3$) | 1.93 |
| Lime ($CaO$) | 1.48 |
| Magnesia ($MgO$) | 1.66 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | 3.19 |
| Loss on ignition | 8.26 |
| | 94.06 |

*Taylorsville clay.*—Five miles north of Taylorsville, on property belonging to J. S. Eaton and brother, on Fisher Creek, the typical Grand Gulf clay of the southeastern area outcrops. It is a dark-gray clay containing a large amount of carbonaceous matter, which is driven off under a high heat and the burned clay is of a buff color. A sample of the clay was sent by J. S. Eaton to the St. Louis Fire Brick Company to be tested for fire brick. It was found, however, that the clay, when used alone, cracked too much in burning. The following analysis has been made of this clay:

*Analysis of Taylorsville clay, Smith County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 71.29 |
| Alumina ($Al_2O_3$) | 16.78 |
| Ferric oxide ($Fe_2O_3$) | 3.30 |
| Lime ($CaO$) | .14 |
| Magnesia ($MgO$) | .41 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | 1.28 |
| Loss on ignition | 6.60 |
| | 99.80 |

*Laurel brick clay.*—At Laurel, Jones County, the Lafayette is very thin and in places entirely washed away. The underlying Grand Gulf clay is dark gray to bluish in color and is well adapted to making common brick. The clay is high in silica, but contains sufficient alumina to bond it. It is claimed by the manager of the Laurel Brick Company that it is almost impossible to burn the clay too hard with wood fuel. The amount of iron in the clay causes the brick to burn to a deep-red color. The following is an analysis of the Laurel clay:

*Analysis of Laurel brick clay, Jones County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 84.86 |
| Alumina ($Al_2O_3$) | 5.28 |
| Ferric oxide ($Fe_2O_3$) | 3.96 |
| Lime ($CaO$) | .23 |
| Magnesia ($MgO$) | .45 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | 1.22 |
| Loss on ignition | 3.66 |
| | 99.66 |

## LAFAYETTE CLAYS (EARLY QUATERNARY).

The prevailing materials of the Lafayette formation are gravels and sand, but occasionally small, irregular deposits of clay are embedded in the coarse sand. The clay when present is usually greatly discolored by the presence of iron oxide, though in some places, as at Morton, Scott County, bodies of snow-white clay are found with scarcely a trace of iron.

In certain localities of the State the surface soil formed from the Lafayette is used in making common brick, but such brick are always high in sand and a very inferior product unless the soil is mixed with a more aluminous material.

The clays of the Lafayette have received very little attention, since they are usually inferior in quality and very limited in quantity. The two samples which are mentioned below show the character of the purer clays embedded in the coarse Lafayette sands.

*Brandon clay.*—In the vicinity of Brandon more or less Lafayette sands overlie the older formations. Within these sands are small, irregular deposits of clay, which is usually nonplastic and highly colored, owing to the presence of iron oxide. The following is an analysis of the Brandon clay:

*Analysis of Brandon clay, Rankin County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 64.79 |
| Alumina ($Al_2O_3$) | 21.35 |
| Ferric oxide ($Fe_2O_3$) | 3.58 |
| Lime (CaO) | .14 |
| Magnesia (MgO) | .70 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | 1.40 |
| Loss on ignition | 7.36 |
| | 99.32 |

*Morton clay.*—One mile east-northeast of Morton, Scott County, at the old gravel pit of the Alabama and Vicksburg Railway, there is a good exposure of the Lafayette sands, pebbles, and the accompanying clay. The uppermost bed consists of Lafayette pebbles and coarse sand, 12½ feet thick. This is underlain by 5 feet of very plastic clay. The upper portion of the clay is interstratified with yellow to red clay and sand and the purest part is near the bottom, where it has a deep, orange-red color, with milky-white spots. The clay is often so tough that it can only be removed from the bank with the greatest difficulty. The analysis of this clay shows it to be low in silica and high in alumina, with very little ferric oxide.

*Analysis of Morton clay, Scott County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 47.40 |
| Alumina ($Al_2O_3$) | 36.72 |
| Ferric oxide ($Fe_2O_3$) | .96 |
| Lime (CaO) | .24 |
| Magnesia (MgO) | .19 |
| Sulphur trioxide ($SO_3$) | Trace. |
| Moisture | 1.09 |
| Loss on ignition | 13.28 |
| | 99.88 |

### LOESS AND YELLOW-LOAM BRICK CLAYS (QUATERNARY).

The yellow loam represents the latest deposit in northern Mississippi except the more recent deposits in the Yazoo bottom and along the streams. It was called yellow or brown loam by Dr. E. W. Hilgard, and was referred to by W J McGee as the Columbia.

In northwestern Mississippi, east of the Yazoo bottom, the loess and yellow loam overlie the Lafayette and form the surface soil of the region. From this loam the brick plants at Holly Springs, Oxford, Grenada, Yazoo City, Jackson, Vicksburg, and other places obtain material for making brick. It is an excellent clay for making wet-mud and dry-pressed brick. It burns from a buff to a deep-red color. Forming the surface of so large an area, it is accessible at almost any place and can be made into brick at a minimum cost.

*Analysis of Ballard clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 63.95 |
| Alumina ($Al_2O_3$) | 21.42 |
| Ferric oxide ($Fe_2O_3$) | 3.88 |
| Lime (CaO) | .39 |
| Magnesia (MgO) | .73 |
| Sulphur trioxide ($SO_3$) | .29 |
| Moisture | 1.74 |
| Loss on ignition | 7.39 |
| | 99.79 |

*Red Bank clay.*—One of the best localities for studying the lenticular character of the Wilcox is in the high divide between the waters of Chewalla Creek on the north and Red Bank Creek on the south, in the vicinity of Red Bank station, in sec. 16, T. 3 S., R. 4 W. About one-half mile south of the station is a large abandoned field from which the Lafayette has been mostly eroded. In places the gullies are washed out 20 feet deep and the whole field is fantastically carved into miniature landscapes. The Wilcox here contains numerous lenses of white, gray, and pink clays, many of which are highly plastic and free from sand. In places the gullies are deep enough to show the full thickness of the clay deposits—not more than 3 to 4 feet on an average. A sample of clay was taken from a large lenticular body on the roadside one-fourth mile south of the church. It burned to a buff color and is flecked with small brown to reddish spots. Below is an analysis of the Red Bank clay.

*Analysis of Red Bank clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 65.88 |
| Alumina ($Al_2O_3$) | 21.19 |
| Ferric oxide ($Fe_2O_3$) | 2.89 |
| Lime (CaO) | .72 |
| Magnesia (MgO) | .15 |
| Sulphur trioxide ($SO_3$) | .30 |
| Moisture | 1.23 |
| Loss on ignition | 7.02 |
| | 99.38 |

*Hern clay.*—This deposit occurs on the roadside about 3½ miles north of Holly Springs and about one-half mile north of the old pit from which the Holly Springs Stoneware and Fire-Brick Company formerly obtained clay for making stoneware. The Hern clay occurs in stratified layers with sand partings. It has a bluish tint, is very plastic, and burns to a buff color very similar to that of the Red Bank clay. Its relation to the Lafayette is shown in the section below.

*Section 3½ miles north of Holly Springs.*

| | Feet. |
|---|---|
| 4. Lafayette sands with ferruginous sandstone at base | 10-12 |
| 3. Stratified plastic clay of a bluish tint, in places containing a small amount of sand | 3 |
| 2. Gray laminated clay 1 to 4 inches thick, alternating with layers of gray sand of about equal thickness | 4 |
| 1. Yellowish laminated sand and clay containing nodules of iron oxide | 5 |

This clay has been analyzed with the following results:

*Analysis of Hern clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 60.78 |
| Alumina ($Al_2O_3$) | 24.12 |
| Ferric oxide ($Fe_2O_3$) | 3.52 |
| Lime (CaO) | .73 |
| Magnesia (MgO) | .38 |
| Sulphur trioxide ($SO_3$) | .38 |
| Moisture | 1.84 |
| Loss on ignition | 8.25 |
| | 100.00 |

*Holly Springs clay.*—The clay deposit at Holly Springs is in a large branch on the west side of the Illinois Central Railroad, about one-fourth mile north of the depot. The clay is a bluish gray with yellow horizontal streaks through it, giving it a laminated appearance. A small amount of gray sand is embedded in the clay. The deposit is not continuous for more than 25 feet and is 4½ feet thick. It is overlain by 10 feet of deep Indian-red Lafayette. An interesting feature of this deposit is the large number of small lenses of highly plastic clay in the sand around the large deposit. Some of these small bodies are 2 feet long and from 1 to 2 inches thick. They are not very far distant from the larger mass and are entirely wanting in the Lafayette. The following is an analysis of this clay:

*Analysis of Holly Springs clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 67.02 |
| Alumina ($Al_2O_3$) | 20.89 |
| Ferric oxide ($Fe_2O_3$) | 2.93 |
| Lime (CaO) | .67 |
| Magnesia (MgO) | .55 |
| Sulphur trioxide ($SO_3$) | .49 |
| Moisture | .96 |
| Loss on ignition | 6.70 |
| | 100.21 |

*Dunlap clay.*—A clay deposit occurs on Joe Dunlap's land in the cut where the Holly Springs and Pontotoc road crosses the Frisco Railroad. The clay is horizontally bedded and is exposed for a distance of 350 feet along the cut, with a thickness of 2 feet showing above the surface. It is a tough, white, siliceous clay, flecked with small particles of mica and burns to a cream-white. It is overlain by 6 to 7 feet of micaceous clayey sand. The top of the hill is covered with 6 to 7 feet of yellow loam. The following analysis has been made of the Dunlap clay:

*Analysis of Dunlap clay, Marshall County.*

[By W. F. Hand, State Chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 62.41 |
| Alumina ($Al_2O_3$) | 24.02 |
| Ferric oxide ($Fe_2O_3$) | 2.80 |
| Lime (CaO) | .57 |
| Magnesia (MgO) | .50 |
| Sulphur trioxide ($SO_3$) | .56 |
| Moisture | .66 |
| Loss on ignition | 7.25 |
| | 98.77 |

*Holly Springs stoneware clay.*—One and one-half miles east of the Holly Springs depot is a small area comprising 20 or 30 acres from which the Holly Springs Stoneware Company gets the clay for making its ware. The clay occurs in large lenticular masses with a maximum length of 80 feet. Perhaps 25 yards from the point where one of these lenses cuts out, another large lens, or "mountain," as the clay digger calls it, will begin. The greatest thickness of the clay so far penetrated is 18 feet, and the bottom was not then reached. One pit is used until it gets too deep to throw the clay out with a shovel or until a rain fills it with water, and it is then abandoned and another opened. Small deposits of pure sand, from 1 inch to 1 foot thick and 2 to 3 feet long, often occur in the center of the clay lenses. The digger reports that numerous leaf impressions are found at a depth of 10 to 12 feet. Clay coming from a depth of 10 feet works better than that near the surface. This clay is very plastic, free from sand, and has to be mixed with a more sandy clay before it is made into stoneware. It burns to a cream color under high heat. The following is an analysis of this clay:

*Analysis of Holly Springs stoneware clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 67.70 |
| Alumina ($Al_2O_3$) | 19.69 |
| Ferric oxide ($Fe_2O_3$) | 3.04 |
| Lime (CaO) | 1.06 |
| Magnesia (MgO) | .58 |
| Sulphur trioxide ($SO_3$) | .19 |
| Moisture | .94 |
| Loss on ignition | 6.64 |
| | 99.84 |

*Allison stoneware clay.*—The clay used by the Allison pottery comes from a pit along the same branch as the Holly Springs stoneware-clay pit. The Allison clay differs from the other clay in being stratified instead of occurring in lenses. At the top of the pit are 4 to 5 feet of Lafayette, below which are 10 feet of clay. The upper half of the clay is more arenaceous than the lower and has a pinkish color. The lower half is a white plastic clay which is used for making stoneware. Immediately below the white clay is a thin band of lignite, and this in turn is underlain by 4 to 5 feet of variegated sands. A glance at the sands shows white, black, red, orange, yellow, and blue colors. The following analysis shows the composition of the Allison clay:

*Analysis of Allison stoneware clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 61.69 |
| Alumina ($Al_2O_3$) | 24.91 |
| Ferric oxide ($Fe_2O_3$) | 2.04 |
| Lime (CaO) | .34 |
| Magnesia (MgO) | .83 |
| Sulphur trioxide ($SO_3$) | .20 |
| Moisture | 1.51 |
| Loss on ignition | 8.07 |
| | 99.59 |

*Frisco fire clay.*—About 100 yards east of the Frisco depot at Holly Springs is a deposit of white sandy clay which is made into fire brick and used in lining the kilns of the Holly Springs Stoneware Company. The bricks stand the highest degree of heat required in burning the ware without going to pieces. In appearance the clay is little more than a mass of slightly bonded sand which occurs at the surface in large bodies and is distinct in color from the loose variegated sands in the vicinity. The following is an analysis of this clay:

*Analysis of Frisco fire clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 88.52 |
| Alumina ($Al_2O_3$) | 5.26 |
| Ferric oxide ($Fe_2O_3$) | 1.64 |
| Lime (CaO) | .73 |
| Magnesia (MgO) | .13 |
| Sulphur trioxide ($SO_3$) | .43 |
| Moisture | .87 |
| Loss on ignition | 1.93 |
| | 99.51 |

A clay very similar to the one above mentioned, as is shown by the analysis given below, occurs just south of the Frisco depot:

### *Analysis of Frisco fire clay No. 2, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 84.40 |
| Alumina ($Al_2O_3$) | 6.79 |
| Ferric oxide ($Fe_2O_3$) | 1.30 |
| Lime ($CaO$) | .85 |
| Magnesia ($MgO$) | .27 |
| Sulphur trioxide ($SO_3$) | .17 |
| Moisture | .74 |
| Loss on ignition | 5.36 |
| | 99.88 |

*Whitelock clay.*—The Whitelock clay outcrops at the spring where the Illinois Central Railroad crosses the public road, 2 miles south of Holly Springs. It is a white plastic clay flecked with mica, and occurs in stratified sands 40 feet below the base of the Lafayette. It burns to a cream color. An analysis of this clay is given below:

### *Analysis of Whitelock clay, Marshall County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 66.66 |
| Alumina ($Al_2O_3$) | 22.29 |
| Ferric oxide ($Fe_2O_3$) | 1.57 |
| Lime ($CaO$) | .62 |
| Magnesia ($MgO$) | .28 |
| Sulphur trioxide ($SO_3$) | .11 |
| Moisture | 1.23 |
| Loss on ignition | 2.41 |
| | 95.17 |

*Wyley clay.*—A very white nonplastic clay occurs in stratified layers near the house of Sid. Wyley, in sec. 16, T. 8 S., R. 4 W., Lafayette County. The following section was taken from the gully in which the clay outcrops:

### *Section on Wyley place, in sec. 16, T. 8 S., R. 4 W.*

| | Feet. |
|---|---|
| 5. Yellow loam and Lafayette at surface. | |
| 4. Impure sandy clay | 2 |
| 3. White plastic clay from which sample was taken | 10 |
| 2. Impure yellow clay | 1½ |
| 1. Whitish-gray sand to bottom of gully | 2 |

At the base of the yellow clay is a thin band of ferruginous sandstone and numerous concretions of iron clay stones. The following analysis has been made of this clay:

### *Analysis of Wyley clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 57.48 |
| Alumina ($Al_2O_3$) | 26.94 |
| Ferric oxide ($Fe_2O_3$) | 2.43 |
| Lime ($CaO$) | .78 |
| Magnesia ($MgO$) | .27 |
| Sulphur trioxide ($SO_3$) | .20 |
| Moisture | 1.64 |
| Loss on ignition | 8.99 |
| | 98.73 |

*Callicoatt clay.*—An outcrop of clay occurs near C. C. Callicoatt's house, in sec. 16, T. 9 S., R. 3 W. This clay is slightly yellowish, free from sand, and burns to a rich cream color. There is an old Indian pottery near by, with numerous pieces of pottery which were made from this clay bank. The following is an analysis of the Callicoatt clay:

*Analysis of Callicoatt clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 68.75 |
| Alumina ($Al_2O_3$) | 19.57 |
| Ferric oxide ($Fe_2O_3$) | 1.68 |
| Lime (CaO) | .56 |
| Magnesia (MgO) | .19 |
| Sulphur trioxide ($SO_3$) | .13 |
| Moisture | .90 |
| Loss on ignition | 6.17 |
| | 97.95 |

*Moss clay.*—This clay outcrops in a deep gully on the public road just in front of a negro cabin on Robert Moss's land. The Lafayette rests directly on the clay, which occurs in a lenticular mass in the variegated sands of the Wilcox formation. The clay is free from grit, very fat, and has a pinkish tinge. The thickness of the deposit is at least 10 feet. Below is an analysis of the Moss clay:

*Analysis of Moss clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 70.56 |
| Alumina ($Al_2O_3$) | 19.03 |
| Ferric oxide ($Fe_2O_3$) | 2.27 |
| Lime (CaO) | .49 |
| Magnesia (MgO) | .13 |
| Sulphur trioxide ($SO_3$) | .19 |
| Moisture | .63 |
| Loss on ignition | 6.66 |
| | 99.96 |

*Miller clay.*—In the vicinity of George Miller's house, in sec. 8, T. 8 S., R. 3 W., are large bodies of very lean, nonplastic soapstone or clay which often cover an acre or more. The clay is almost snow white and, where the Lafayette has been removed, can be seen for a long distance before reaching the outcrop. These deposits occur in horizontal laminæ one-fourth inch to 2 inches thick. More or less mica is present throughout, with a large amount of highly siliceous material. This clay has been analyzed with the following results:

*Analysis of Miller clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 85.78 |
| Alumina ($Al_2O_3$) | 6.68 |
| Ferric oxide ($Fe_2O_3$) | 1.30 |
| Lime (CaO) | .48 |
| Magnesia (MgO) | .14 |
| Sulphur trioxide ($SO_3$) | .32 |
| Moisture | .73 |
| Loss on ignition | 2.37 |
| | 97.80 |

*Oxford clay.*—A sample of clay was obtained from the deep gully near the colored-school building in the town of Oxford. On all sides of the town the variegated coarse sands of the Wilcox appear in the gullies and along the roads and railroad. The sand is highly cross-bedded. The sample of clay was taken in this cross-bedded sand at the base of the Lafayette. The clay is plastic, free from grit, and burns to a white color. The following is an analysis of this clay:

### *Analysis of Oxford clay, Lafayette county.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 57.79 |
| Alumina ($Al_2O_3$) | 26.03 |
| Ferric oxide ($Fe_2O_3$) | 2.98 |
| Lime (CaO) | .44 |
| Magnesia (MgO) | .10 |
| Sulphur trioxide ($SO_3$) | .24 |
| Moisture | 1.14 |
| Loss on ignition | 9.11 |
| | 97.83 |

*Russell clay.*—A stratified plastic gray clay outcrops in a deep gully on Walsh Russell's land, in Lafayette County, and has been analyzed as follows:

### *Analysis of Russell clay, Lafayette County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 51.88 |
| Alumina ($Al_2O_3$) | 30.64 |
| Ferric oxide ($Fe_2O_3$) | 3.53 |
| Lime (CaO) | .58 |
| Magnesia (MgO) | .60 |
| Moisture | 1.16 |
| Loss on ignition | 10.14 |
| | 98.53 |

*Grenada clay No. 1.*—At the wagon bridge across Yalobusha River at Grenada the dark-blue lignitic clay of the upper Wilcox formation outcrops in the river bank, where there is an exposure of this clay 20 feet thick. It is overlain by more sandy clays, which alternate with strata of micaceous sand to the top of the high hill west of Grenada. There is more or less fine siliceous sand and mica in the dark clay at the bridge. When burned the clay becomes a pale rusty red, owing to the presence of iron oxide. The following is an analysis of this clay:

### *Analysis of Grenada clay No. 1, Grenada County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 61.80 |
| Alumina ($Al_2O_3$) | 16.50 |
| Ferric oxide ($Fe_2O_3$) | 3.88 |
| Lime (CaO) | 1.00 |
| Magnesia (MgO) | .23 |
| Sulphur trioxide ($SO_3$) | .19 |
| Moisture | 5.91 |
| Loss on ignition | 8.75 |
| | 98.26 |

*Grenada clay No. 2.*—At the foot of the high range of hills 1 mile east of Grenada, on the public road, is a very siliceous clay belonging to the Wilcox formation. This has been analyzed as follows:

### *Analysis of Grenada clay No. 2, Grenada County.*

[By W. F. Hand, State chemist.]

| | |
|---|---|
| Silica ($SiO_2$) | 90.33 |
| Alumina ($Al_2O_3$) | 2.85 |
| Ferric oxide ($Fe_2O_3$) | 1.49 |
| Lime (CaO) | .71 |
| Magnesia (MgO) | .14 |
| Sulphur trioxide ($SO_3$) | .19 |
| Moisture | .58 |
| Loss on ignition | 1.45 |
| | 97.74 |

(3) Tertiary limestones (Vicksburg limestone).

The distribution of these formations is shown on the geologic map (Pl. I), which is based on recent work by the United States Geological Survey in Mississippi.

### MISSISSIPPIAN (LOWER CARBONIFEROUS) LIMESTONES.

In the extreme northeast corner of Mississippi, in the counties of Itawamba and Tishomingo, there is a small area of Devonian and Carboniferous rocks. These include shales, thin sandstones, and limestones. The limestones, which are mainly of Mississippian (Lower Carboniferous) age, are frequently low in magnesia, and are otherwise suitable for use as Portland cement material. At present, however, the most promising localities of these limestones have no adequate transportation facilities. This fact, together with the nearness of the soft and easily crushed Selma chalk, will probably serve to prevent the utilization of the Carboniferous limestones for some time.

The following analysis of a limestone from Cypress Pond, Tishomingo County, is by Dr. E. W. Hilgard:

*Analysis of Mississippian limestone.*

| | |
|---|---|
| Silica ($SiO_2$) | 1.68 |
| Alumina ($Al_2O_3$)<br>Iron oxide ($Fe_2O_3$) | .58 |
| Lime (CaO) | 53.49 |
| Magnesia (MgO) | .82 |
| Carbon dioxide ($CO_2$) | 42.03 |
| Water | 1.34 |

### CRETACEOUS LIMESTONE (SELMA CHALK, OR "ROTTEN LIMESTONE").

The Selma formation of the Cretaceous is a thick series of chalks, chalky limestones, and more or less limy clays, which are well exposed in northeastern Mississippi. The area occupied by these limestones in Mississippi is shown in Pl. I.

*Thickness.*—The Selma chalk attains its maximum thickness in central Alabama, reaching a total of about 1,200 feet. To the west it decreases slightly in thickness, the well at Livingston, Sumter County, Ala., giving a total of 930 feet, while the well at Starkville, Oktibbeha County, Miss., taken in connection with surrounding outcrops, indicates a thickness of at least 700 feet. As the belt turns northward toward Tennessee the formation decreases rapidly in thickness, while at the same time the limestone beds contained in it become fewer and thinner, until in Tennessee the Selma is a thin series of somewhat calcareous clays, with only occasional beds of chalk.

*Stratigraphy.*—Owing to the rapidity with which it disintegrates when exposed to atmospheric action, surface outcrops give comparatively little information in regard to the stratigraphy of this formation. Fortunately, a very precise section of the Selma chalk, taken at a point where it is almost of maximum thickness, is in existence. This is embodied in the record of a well drilled at Livingston, Sumter County, Ala., and quoted by Dr. E. A. Smith in his Report on the Geology of the Coastal Plain of Alabama, pages 277–278. The well was located just south of the boundary between the Selma and Ripley formations, and reached a depth of 1,062 feet, so that it passed through the entire thickness of the Selma chalk and into the underlying Eutaw formation.

The section of this well is given below. The upper 20 feet are, according to Smith, probably in part Lafayette and in part Ripley. From a depth of 20 to 950 feet the well was in the Selma formation, while from 950 to 1,062 feet it was in the Eutaw.

*Section of well at Livingston, Sumter County, Ala.*

| | Thickness. | Depth. |
|---|---|---|
| Lafayette and Ripley: | *Feet.* | *Feet.* |
| Sandy loam | 1 | |
| Coarse, dry sand | 12 | 1 - 13 |
| White quicksand | 7 | 13 - 20 |
| Selma chalk: | | |
| Soft blue limestone, many shells and pyrite nodules | 180 | 20 - 200 |
| White limestone, harder, few shells or pyrite nodules | 50 | 200 - 250 |
| Hard blue limestone, no shells or nodules | 7 | 250 - 257 |
| Bluish-white limestone, less hard, no shells or nodules | 68 | 257 - 325 |
| White limestone, very hard | 55 | 325 - 380 |
| Light-blue limestone, softer | 47 | 380 - 427 |
| Bluish-brown rock, small shells, some sand | 58 | 427 - 485 |
| Hard white limestone | 105 | 485 - 590 |
| Soft reddish-brown rock | 2 | 590 - 592 |
| Soft deep-blue rock | 20 | 592 - 612 |
| Brownish-blue rock, moderately soft | 78 | 612 - 690 |
| Hard, gritty blue rock | ½ | 690 - 690½ |
| Dark-bluish rock, soft | 9½ | 690½- 700 |
| Soft whitish limestone | 250 | 700 - 950 |
| Eutaw sands: | | |
| Hard sandstone | 6 | 950 - 956 |
| Sand | 10 | 956 - 966 |
| Sand rock | 1 | 966 - 967 |
| Coarse greensand | 38 | 967 -1,005 |
| Sandstone | 2 | 1,005 -1,007 |
| Greensand | 25 | 1,007 -1,032 |
| Sandstone | 2 | 1,032 -1,034 |
| Coarse greensand | 18 | 1,034 -1,052 |
| Flint rock | 1 | 1,052 -1,053 |
| Very fine greensand | 9 | 1,053 -1,062 |

*Description of localities.*—During 1904 the Selma chalk was carefully mapped throughout the Tombigbee River basin. The result of this mapping is shown in Pl. I. In the following pages descriptions will be given of the various localities visited during this work. Samples were taken from all of these localities, and many of these samples have been analyzed, the results being given below. The descriptions are given in order, going up Tombigbee River from the Alabama-Mississippi line.

At the big elbow bend in Oaknoxubee River, one-fourth mile below the wagon bridge at Macon, the river has formed on its south side a bluff 75 feet high. The entire cliff is made up of the Selma chalk. It is a solid mass of white chalk, nonfossiliferous, and apparently without bedding planes, but viewed at a distance the stratification of the material is shown by the unequal hardness of the strata, causing some to weather more rapidly than others. There is a marked dip to the south. All the smaller streams flowing into the Oaknoxubee have channeled their beds into the pure white limestone. A sample was collected from the bluff on Oaknoxubee River and has been analyzed in the laboratory of the United States Geological Survey, as follows:

*Analysis of Selma limestone from bluff near Macon.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 9.09 |
| Alumina ($Al_2O_3$) | 7.47 |
| Iron oxide ($Fe_2O_3$) | |
| Lime carbonate ($CaCO_3$) | 80.99 |
| Water | 1.08 |

The town of Scooba is in the Flatwoods area, which is underlain by clays of the Midway group. The road from Scooba to De Kalb is through the Porters Creek area until Sucarnochee Creek is reached, 2 miles east of De Kalb. The hills of the Wilcox formation begin just west of the creek and rise 250 feet above it, barometric reading. The material here forming the Flatwoods is a gray, plastic, nonfossiliferous clay ("popping clay"). It makes a cold soil, very sticky and plastic when wet, and when it dries out cracks open so that one can thrust his hand 6 or 8 inches into the opening.

But little of the Flatwoods area is cleared and put in cultivation, and this only where there is a little remnant of Lafayette sand left. The Lafayette formation is practically wanting over the entire area of the Flatwoods. The timber is short-leaf pine, post oak, scrub hickory, black jack, and black gum, with an occasional white oak and holly.

Two and one-half miles east of Scooba, on the west bank of the creek shown on the map (Pl. I), is the first outcrop of Selma chalk on the Scooba and Gainesville road. A sample of limestone taken from this outcrop was analyzed in the laboratory of the United States Geological Survey, with the following result:

*Analysis of Selma limestone from creek near Scooba.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 16.48 |
| Alumina ($Al_2O_3$) | 6.97 |
| Iron oxide ($Fe_2O_3$) | |
| Lime carbonate ($CaCO_3$) | 74.34 |
| Magnesium carbonate ($MgCO_3$) | .67 |
| Water | .67 |

There is a change in the character of timber as soon as the Selma area is reached. Short-leaf pine, which occurs so abundantly in the Flatwoods, is wanting except in the old "turned-out land." Black oak is the principal timber in the Selma chalk. Some post oak and hickory occur. The pine is wanting at a distance of 2 miles east of Scooba, which would perhaps bring the contact between the Selma and Porters Creek one-half mile west of the Selma outcrop.

Two miles east of Scooba and one-half mile south is another outcrop of limestone, more sandy than that 2½ miles east of Scooba. This is perhaps of Ripley age.

Between Portersville and Oakgrove, in southern Kemper County, on the west side of Pittiefaw Creek, the Wilcox hills begin and extend westward. On land belonging to M. L. Nailer a bed of lignite, reported to be 4 feet thick, has been opened.

Sucarnochee Creek marks the west edge of the Porters Creek group from 2½ miles due east of De Kalb to about 3 miles north of Oakgrove. Here the Porters Creek area widens and its west edge swings in to within 2½ or 3 miles east of Oakgrove, then follows a southeasterly direction and crosses the Kemper and Lauderdale County line about 3½ miles west of the State line.

On the west side of Quilby Creek, where it runs south along the State line, 7 miles east of Sucarnochee, the Selma chalk forms a small bluff. The prairie soil extends back for 2 miles farther west. On the east side of the creek, about 100 yards east of the Alabama line, the Selma forms a bluff a little higher than on the opposite bank in Mississippi. Here what is taken to be the top of the Selma chalk is found. The top of the bluff is capped by a coarse-grained sandstone, cemented by lime carbonate. In it are lime concretions the size of a closed hand..

The upper beds of the Selma chalk also appear in the bluff on the east side of Quilby Creek, 7 miles east of Sucarnochee.

An outcrop of Selma chalk shows on the Scooba and Fox Prairie road where it crosses Bodca Creek, about 2 miles west of the State line. A sample collected from this outcrop was analyzed in the laboratory of the United States Geological Survey, as follows:

*Analysis of Selma limestone from Bodea Creek, near Scooba.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 10.60 |
| Alumina ($Al_2O_3$)<br>Iron oxide ($Fe_2O_3$) | 5.90 |
| Lime carbonate ($CaCO_3$) | 82.47 |
| Magnesium carbonate ($MgCO_3$) | Trace. |
| Water | .82 |

Three miles north of Scooba the western border of the Selma chalk outcrops in a series of hills forming the south bank of Wahalak Creek. The bottom of the Wahalak is here 1½ miles wide, the south bank retreating more rapidly than the north side. The creek has cut its channel into the Selma chalk, which outcrops almost continuously throughout its course. The limestone occurs up the creek about 6½ to 7 miles northwest of Wahalak, but the Porters Creek clay occupies the country on both sides of the creek. The hill just east of Wahalak is of Porters Creek clay, which is not over 15 feet thick.

A sample of limestone was collected from the bed of Wahalak Creek, about 1½ miles south of Wahalak. This sample was analyzed in the laboratoty of the United States Geological Survey, with the following results:

*Analysis of Selma limestone from Wahalak Creek, near Wahalak.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 20.00 |
| Alumina ($Al_2O_3$)<br>Iron oxide ($Fe_2O_3$) | 8.92 |
| Lime carbonate ($CaCO_3$) | 68.91 |
| Magnesium carbonate ($MgCO_3$) | Trace. |
| Water | 1.03 |

A sample of the Selma limestone was taken from the bed of Wahalak Creek, 1½ miles south of the town, and on the range of low hills south of Wahalak Creek, 1½ miles southeast of the point where the Mobile and Ohio Railroad crosses the creek, another sample was taken. At the top of the Selma chalk there is about 10 feet of a sand rock cemented with lime carbonate, which contains numerous little bivalve shells. This is the same kind of stone as that found 7 miles east of Sucarnochee. There is no evidence of any Clayton limestone anywhere from Wahalak to the Alabama line, and this is the only place where the sandstone was seen in Mississippi. This doubtless belongs to the Ripley.

The Porters Creek or Flatwoods clay is well shown near Scooba. A sample collected was analyzed in the laboratory of the United States Geological Survey. The result is of interest, because clays of this type occur everywhere near the western edge of the Selma limestone area, and such clays will be needed to reduce the percentage of lime carbonate found in some of the purer samples of Selma chalk.

*Analysis of Midway clay from Scooba.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 61.92 |
| Alumina ($Al_2O_3$) | 19.47 |
| Iron oxide ($Fe_2O_3$) | 2.81 |
| Magnesia ($MgO$) | 1.98 |
| Soda ($Na_2O$) | .50 |
| Loss on ignition | 12.29 |

A sample of Selma chalk was taken from an old rock quarry situated on the southwest side of Bogue Chitto Creek, one-half mile east of Prairie Rock. This limestone differs from that along Oaknoxubee River, in the vicinity of Macon, in that it is much harder. In the unweathered state of the Macon rock, it is very soft and noncrystalline. One can easily stick a pick into it. But the limestone at Prairie Rock is a hard so-called "flint rock," crystalline in character, and is used for building purposes. The rock at Macon, when exposed to the weather, becomes white as chalk; that at Prairie Rock weathers to a dirty gray and contains some traces of iron stain on the weathered surfaces. This is due to the oxidation of the iron sulphide (pyrite), which is found in small concretions in the fresh rock.

An analysis of this Prairie Rock limestone, made in the laboratory of the United States Geological Survey, follows. It will be seen that the stone is a very pure limestone, in spite of the manner in which it discolors on weathering.

*Analysis of Selma limestone from Prairie Rock.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 1.13 |
| Alumina ($Al_2O_3$)<br>Iron oxide ($Fe_2O_3$) | .68 |
| Lime carbonate ($CaCO_3$) | 98.36 |
| Magnesium carbonate ($MgCO_3$) | Trace. |
| Water | .40 |

The rock breaks down easily when exposed to the weather, and hence is not now used for extensive building purposes. It is, however, the only road material found in this section of the country. It has been used on the road across Bogue Chitto swamp, but is unsatisfactory.

Men familiar with the country say that this hard limestone is very thin—only about 4 feet thick—and occurs near the surface. Below this hard stratum comes the soft, whiter "rotten limestone," which is, on an average, 20 feet thick and is underlain by the "blue rock," which holds water. In digging cisterns, the farmers always dig down to the "blue rock," which requires no curbing.

There are two kinds of soils in the prairie section, giving rise respectively to the "post-oak" land and the "prairie" proper. The former is the highest land between the stream divides, which has suffered but little erosion. It is very level, sloping gently to the streams. This post-oak land is covered with a thin coating of Lafayette clayey sand, never over 10 feet thick, which has never been all carried away by erosion. The uncleared land produces post-oak and some black-oak timber. The "prairie" land is that from which the Lafayette has been removed, so that the black, rich loam, formed from the decomposition of the Selma chalk, is at the surface. The limestone never comes to the surface except along the streams.

When the country was first settled this black prairie soil was too strong for cotton. It produced a large stalk, but very little cotton. Until recent years all the cotton was planted on the poorer "post-oak" lands, and the prairie lands were put in corn. But after years of continuous crops of corn the prairie land became the best cotton land, and now the finest cotton grows on the prairie lands.

Later investigation around Columbus and Aberdeen has verified the fact that the land known by all as the "post-oak land," as distinguished from the black "prairie soils," is the land from which the entire Lafayette has not been removed. The soil is not so rich as the prairie soils, and has been largely abandoned for cultivation.

The following well sections are of interest in this connection:

*Well at Ravine, on land of J. Q. Poindexter.*

| | Feet. |
|---|---|
| Selma chalk | 250 |
| Sand, water bearing, and principal source of water | 475 |
| Red clay | 50 |
| Depth | 775 |

Water rises within 26 feet of surface. Water soft.

*Well 2 miles due east of Ravine, on Sebe Gavin's land.*

| | Feet. |
|---|---|
| Depth of well | 431 |

Water flows 16 feet above surface.

*Well on Doctor Patty's land, near Bigbee Valley post-office.*

| | Feet. |
|---|---|
| Depth of well | 431 |

Water flows 20 feet above surface. Water found in sand, and soft.

*Well at Bigbee Valley post-office, sec. 16, T. 16, R. 19 E.*

| | Feet. |
|---|---|
| Depth of well | 460 |
| Thickness of Selma chalk | 200 |

Water flows 20 feet above surface.

*Well in sec. 21, T. 16, R. 19 E.*

| | Feet. |
|---|---|
| Depth of well | 444 |
| Thickness of sand | 200 |

Flows.

*Well at Cliftonville.*

| | Feet. |
|---|---|
| Limestone | 300 |
| Dark sand, dry | 20 |
| White sand, water bearing | 20 |
| Dark sand, dry | 10 |
| White sand, watar bearing | 40 |
| Ferruginous sandstone | 1 |

Depth of well, 450 feet; 300 feet in limestone, 150 feet in sand.
Source of water, greensand.

*Well on A. G. Cunningham's land, 1½ miles west of mouth of James Creek.*

| | Feet. |
|---|---|
| Depth of well | 500 |
| Thickness of limestone | 100 |

Well is 75 feet above Tombigbee River. Water overflows.

*Well at Pickensville, Ala., on land of Will Rodgers.*

| | Feet. |
|---|---|
| Thickness of limestone | 100 |
| Depth of well | 400 |

Flows.

All the wells mentioned above except the first one were drilled by J. B. Cunningham, of Cliftonville, Miss., and the records were obtained from him. The well drillers fail to make any distinction between the lower Selma and the upper Eutaw, so that their records can not be depended on for determining the thickness of the Selma.

A sample of sandy limestone was obtained from the mouth of James Creek, on Tombigbee River. Along the Tombigbee at the mouth of this creek there is an exposure of a greensand clay containing a large amount of lime. Fifty feet above the river, 1½ miles west of the mouth of James Creek, another sample of limestone was collected. This limestone is similar in color and general aspect to that on the Tombigbee, except that it has less greensand.

Farther west the limestone rarely shows at the surface. It is clayey in character and easily dissolved by the weathering agents, so that it breaks down into soil faster than it is carried away by erosion.

At Cliftonville, which is 75 feet above Tombigbee River (barometric reading), there is a hard cap rock, 2 to 4 feet thick, found on top of the hills in the vicinity of the town. This is a hard "lime" rock, similar to that found at Prairie Rock. Below this hard cap rock comes what is called the "blue rock." A sample of it seen at a well dug years ago shows that it contains no sand. Where the blue rock comes to the surface it forms a belt of the richest soil in the prairie region. The soil is very deep, black, and loose. More cotton and corn are raised to the acre here than in any other section of the State.

West of this region the land becomes higher, and the Lafayette occupies the surface on the ridges.

Six miles north of Macon, on the Macon and Columbus road, the limestone begins to show at the surface in small gullies. The rock is harder than the blue rock along the Tombigbee, and therefore occurs more frequently. A sample collected from this locality was analyzed in the laboratory of the United States Geological Survey, as follows:

*Analysis of Selma limestone from 6 miles north of Macon.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 8.52 |
| Alumina ($Al_2O_3$)<br>Iron oxide ($Fe_2O_3$) | 6.60 |
| Lime carbonate ($CaCO_3$) | 83.88 |
| Water | 1.00 |

Farther south, along the Macon and Columbus road, the limestone begins to show in every gully and on every hillside. At some places on level ground the soil is not over 12 inches deep. In this vicinity are the bald prairies, where large areas of this white limestone are exposed without a particle of soil or a blade of grass. A sample of the rock was taken 3 miles north of Macon.

A sample of Selma limestone was taken at a point north of Lime Rock, 5 miles east of Shuqualak, on Oaknoxubee River, where a bluff 50 feet high is composed of typical Selma chalk. The following analysis of this sample was made in the laboratory of the United States Geological Survey:

*Analysis of Selma limestone from bluff near Shuqualak.*

[By W. S. McNeil.]

| | |
|---|---|
| Silica ($SiO_2$) | 8.06 |
| Alumina ($Al_2O_3$)<br>Iron oxide ($Fe_2O_3$) | 5.94 |
| Lime carbonate ($CaCO_3$) | 84.61 |
| Magnesium carbonate ($MgCO_3$) | .06 |
| Water | 1.32 |

Tombigbee River at Columbus has cut its channel into the Eutaw sands, forming a bluff on the east side 90 feet high. The material composing the bluff here is a sand that is greenish when wet and gray when dry. It contains a small amount of lime carbonate. In the upper part of the bluff the sands are of lighter color and at the top they are a light golden yellow. This was the color of the sand when deposited and is not due to oxidation. Numerous little branching concretions, which are perhaps some kind of badly preserved fossils, occur in the lower portion near the water. The upper part of the sands contains two species of large oysters, which also occur in the Selma. The river at the town is now hugging the east bluff, and the bottom, which is 3 miles wide, is all on the west side. A short distance above the town, however, the reverse is true, the bluff being on the west side and the bottom on the east. At the west edge of the bottom the heavy, black prairie soils of the Selma chalk appear as soon as the little hills are reached. The bottom extends northward to the little creek that flows northeastward into the river 3 miles above the town.

At a distance of 4 miles above town the bluff on the west side of the river reaches about the same height above the water as the bluff at Columbus. It extends for 1 mile along the river as a perpendicular cliff that affords a fine section of the upper Eutaw and the base of the Selma. The low hills on the west come down to the top of the bluff. The same heavy, black prairie soils which come within 3 miles of the river due west of Columbus here reach the edge of the bluff.

The following is a section of the bluff obtained where the road comes down to the river:

*Section of bluff of Tombigbee River 4 miles north of Columbus.*

| | Ft. | in. |
|---|---|---|
| Lafayette at top. | | |
| Selma: | | |
| 10. "Blue rock" of the Selma; a white to gray joint clay containing less sand at top than at bottom. In its unweathered condition the clay is pale blue, with green and black sand | 8 | |
| Eutaw: | | |
| 9. Greensand, highly calcareous, and containing numerous large oysters | 5 | |
| 8. Ledge of indurated greensand, calcareous, and containing same fossils as No. 9 | | 12 |
| 7. Lighter colored sand, containing very few small fossils and no large ones | | 14 |
| 6. Greensand, nonfossiliferous | | 6 |

| Eutaw—Continued. | Ft. | in. |
|---|---|---|
| 5. Slightly fossiliferous, gray micaceous sand | 5 | |
| 4. Ledge of indurate sand, slightly fossiliferous | | 10 |
| 3. Greensand, containing same large oysters as No. 9 | 4 | |
| 2. Ledge of indurated sand | | 8 |
| 1. Fossiliferous greensand to the water's edge | 4 | |

The prairie soil of the Selma extends to the river north of Columbus, but is not found east of the river. From Columbus southward to the south side of McCowers Creek on the west side of the river the Tombigbee bottom ranges in width from 2 to 4 miles. South of this creek the bottom changes again to the east side, and the Selma extends to the river.

At the mouth of James Creek the same joint clay that is seen above Columbus occurs on the east bank of the creek, about 10 feet above the water's edge.

Eight miles east of Columbus, on the Columbus and Tuscaloosa road, the hills of the Tuscaloosa formation first appear. On the hill near the 8-mile post the highly stratified clay, interbedded with various colored sands, outcrops on the side of the road.

At Steens Station the creek is cutting into the Eutaw sands.

Where the road crosses Yellow Creek the foundation of the bridge is built on the compact sand, which here is of a deep-gray color and very homogeneous in character.

One mile south of Strongs, on the Monroe and Clay county line, the Illinois Central Railroad has cut into the Selma clay to a depth of 15 feet.

Eutaw sands extend west of the town of Aberdeen for 2 miles. Here the post-oak lands begin, and the regular prairie soils one-half mile farther west. There are no outcrops of the Selma from Aberdeen to Prairie Station. The first outcrop found northwest of Aberdeen is at Strongs. Here, as farther south, outcrops of the Selma are very few on its eastern edge.

The following four analyses are of samples of limestone from various points in Oktibbeha County:

*Analyses of Selma limestone from Oktibbeha County.*

[By W. F. Hand, State chemist.]

| | 1. | 2. | 3. | 4. | Average. |
|---|---|---|---|---|---|
| Silica ($SiO_2$) | 2.89 | 2.33 | 3.03 | 2.55 | 2.70 |
| Alumina ($Al_2O_3$) | 1.53 | 1.72 | 1.92 | 1.96 | 1.78 |
| Iron oxide ($Fe_2O_3$) | | | | | |
| Lime carbonate ($CaCO_3$) | 94.10 | 94.35 | 93.60 | 94.07 | 94.03 |
| Magnesium carbonate ($MgCO_3$) | 1.84 | 1.82 | 1.64 | 2.12 | 1.85 |
| Water | .36 | .44 | .42 | .52 | .44 |

The following analysis of a sample of the Selma chalk from near Okolona, Chickasaw County, Miss., is an old one, made by Doctor Hilgard.[a] Of the material reported as "insoluble," probably about two-thirds was silica, the remainder being alumina and iron oxide.

*Analysis of Selma limestone from Okolona.*

| | |
|---|---|
| Insoluble (mostly silica, $SiO_2$) | 10.90 |
| Alumina ($Al_2O_3$) | 1.96 |
| Iron oxide ($Fe_2O_3$) | 1.42 |
| Lime (CaO) | [b]45.79 |
| Magnesia (MgO) | [c].88 |
| Alkalies ($K_2O$, $Na_2O$) | .57 |
| Carbon dioxide ($CO_2$) | 35.73 |
| Water and organic | 2.84 |

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[a] Geology and Agriculture of Mississippi, 1860, p. 101.
[b] Equals lime carbonate ($CaCO_3$), 81.77.
[c] Equals magnesium carbonate ($MgCO_3$), 1.84.

### TERTIARY LIMESTONE (VICKSBURG LIMESTONE).

A narrow belt of limestone of Tertiary age crosses the State, in a direction a little north of west, from near Waynesboro to Vicksburg. This is the Vicksburg limestone, which is equivalent to the upper part of the St. Stephen limestone of Alabama. The relations which exist may be indicated as follows:

| Mississippi. | | Alabama. |
|---|---|---|
| Vicksburg limestone....... | = | St. Stephen limestone. |
| Jackson marls and clays.. | | |

A very detailed description of the characters and composition of the St. Stephen limestone, as shown in its Alabama outcrop, is given by Doctor Smith on pages 77 to 81 of Bulletin No. 243, while in Pl. I the outcrop across Alabama and Mississippi of the St. Stephen and the Vicksburg-Jackson is indicated.

In Mississippi the Vicksburg limestone usually outcrops in a low ridge that trends generally a little north of west. The southern slope of this ridge is gentle, but its northern face is a sharp declivity, which makes it easy both to locate the outcrop and to quarry the limestone.

The Vicksburg limestone carries usually from 80 to 95 per cent of lime carbonate, with very little magnesium carbonate. Occasionally, however, more clayey phases are encountered, but in general this formation may be everywhere regarded as a possible source of Portland cement material.

The analysis below was recently made on a sample taken several miles south of Jackson, Hinds County:

*Analysis of Vicksburg limestone from near Jackson.*

[By G. T. Hetherington.]

| | |
|---|---|
| Silica ($SiO_2$) | 9.63 |
| Alumina ($Al_2O_3$) | 2.73 |
| Iron oxide ($Fe_2O_3$) | 2.76 |
| Lime (CaO) | 45.95 |
| Magnesia (MgO) | .99 |
| Alkalies ($K_2O$, $Na_2O$) | .95 |
| Sulphur trioxide ($SO_3$) | .35 |
| Carbon dioxide ($CO_2$) | 37.00 |
| Water | |

This corresponds to a content of about 81 per cent lime carbonate, and as the rock is otherwise satisfactory the addition of a little clay will make a suitable Portland cement mixture.

The analyses below were published in the early reports of the Mississippi geological survey. The last two, and perhaps the other three also, were made by Dr. E. W. Hilgard.

*Analyses of Vicksburg limestones.*

| | 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| Silica ($SiO_2$) | 6.30 | 15.05 | 9.20 | 2.03 | 12.31 |
| Alumina ($Al_2O_3$) | 7.20 | 5.35 | 6.65 | 2.12 | 2.70 |
| Iron oxide ($Fe_2O_3$) | | | | | |
| Lime (CaO) | 48.44 | 44.58 | 47.12 | 52.47 | 43.93 |
| Magnesia (MgO) | [a] n. d. | n. d. | n. d. | .67 | 1.69 |
| Alkalies ($K_2O$, $Na_2O$) | n. d. | n. d. | n. d. | n. d. | .79 |
| Sulphur trioxide ($SO_3$) | n. d. | n. d. | n d. | n. d. | 1.27 |
| Carbon dioxide ($CO_2$) | 38.06 | 35.02 | 37.03 | 41.53 | 34.72 |
| Water | n. d. | n. d. | n. d. | 1.10 | 2.40 |

[a] n. d.=not determined.

1-3. Red Hills, Wayne County: Harper, Geology of Mississippi, 1857, p. 166.

4. Brandon, Rankin County: Hilgard, Geology and Agriculture of Mississippi, 1860.

5. Byram, Hinds County: Hilgard, Geology and Agriculture of Mississippi, 1860.

## BUILDING STONE.

The building stones of Mississippi include sandstones and limestones. The limestones have already been described under the heading "Cement materials" (pp. 76–84).

Sandstones from three different geologic formations occur in the northeastern, central, and southern parts of the State. The sandstone from the Chester formation of Tishomingo County is well suited for a durable building stone, but in no place has it been worked, on account of the distance from a railroad or navigable stream. The stone would be easily worked. It occurs in strata 150 feet thick or more along Bear Creek.

The buhrstone of Carroll, Attala, Leake, and Neshoba counties furnishes a hard quartzitic sandstone, which would be well adapted for building stone, railroad ballast, and perhaps glass sand. The cementing material is silica. When freshly dug from below the surface the sandstone is very white, and soft enough to be easily worked. No use is made of this stone except for local purposes, such as foundation stones for houses, etc.

The old capitol building at Jackson was built of Grand Gulf sandstone from near Raymond. The large amount of iron pyrites, in changing from the sulphide to the oxide condition, cracked the stone, and on this account the stone has been abandoned.

Investigation of sandstone from various parts of the Grand Gulf group has shown that the rock varies from a very soft, loosely cemented sand to a hard though somewhat clayey sandstone practically free from iron pyrites.

A quarry is now being opened at Star, Rankin County, by the Indiana and Mississippi Stone and Timber Company. The following is an analysis and test made of the stone by R. W. Evans, director of the chemical laboratory of Purdue University:

> I have made an examination of the sample of stone received from you and described as "Eureka stone from Star, Rankin County, Miss., the deposit being the property of the Indiana and Mississippi Stone and Timber Company (Limited)."
>
> Pieces of the sample were subjected for a considerable time to the greatest heat of the gas-blast lamp, some specimens being heated gradually, others as suddenly as possible, to a bright red heat. In no case was there any sign of melting or of cracking or crumbling, the pieces retaining their original form perfectly, and being quite unchanged in appearance. From the nature of the stone (sandstone) it is also certain that no general chemical change results from this heating, as would occur in limestone.

## ROAD MATERIALS.

Limestones suitable for making roads are found in Tishomingo County. They belong to the Paleozoic rocks and are found only along Tennessee River and its tributaries. The white oolitic limestone of the St. Louis and the more siliceous limestone of the Tullahoma make excellent ballast and road material when crushed.

Sandstone is more widely distributed than the limestones. It overlies the limestone along Bear Creek in Tishomingo County and extends several miles farther south. The Paleozoic sandstone is not good, lasting road material. Constant travel over it soon pulverizes it and reduces it to sand.

The most desirable sandstone for common road material and railroad ballast is the semiquartzite belonging to the Tallahatta buhrstone. It would be more expensive to crush than the limestones, but when once reduced to the proper size it would be more lasting. The largest deposit of the Tallahatta occurs 4 to 5 miles north of Kosciusko.

The Grand Gulf sandstone has been tried for a road material, but has been found to be too soft and rotten.

### GRAVEL OR SHINGLE.

The cheapest and most available road material in the State is shingle or Lafayette gravel. These deposits are widely scattered over various parts of the State, but in only two sections are they of sufficient thickness and extent to become of great economic importance. One of the areas is along the eastern border of the Cretaceous near the foothills of the older rocks in Tishomingo and Itawamba counties. These deposits are often 50 to 75 feet thick and cover large areas. A large per cent of the gravel is quartz, which makes a very desirable road material for constant wear. Intermingled with the gravel is a ferruginated mixture of sand and clay, which forms a natural cement. When placed upon a street or railroad the rains and constant travel over it cause the material to cement into a rock-like mass. Some railroad men object to the gravel from the eastern section of the State because it often cements so tightly that it prevents the ties from drying out and makes the roadbed too rigid. This cementing quality makes it all the more desirable for common road material.

When shipped for any great distance over the railroads gravel becomes an expensive road material. In Coahoma County experiments have recently been made in building roads with gravel from Tishomingo County. The cost of grading and putting a layer of gravel 8 inches thick in the center of the road was $5,000 per mile, or $50 per carload.

The other section of the State where gravel is present is along the western half. This is more extensive than the eastern area, but the deposits are much thinner, the gravel in many places being but a few inches thick. The gravel of the western area does not possess the cementing qualities of the Tishomingo gravel. It is little more than a mass of round, water-worn pebbles which when used as a road material are easily pushed aside by wheels of vehicles and horses' feet. For this reason it has been called "crawling gravel." Where used as a railroad ballast it is greatly improved by being mixed with sand and clay.

### BURNED CLAY.

In some of the later formations of the State there is a bluish-gray to dark-colored tough gumbo clay which has been experimented on for making roads. This clay is found throughout the Yazoo delta region, except where it is covered by silts and sands along the streams.

Some of the citizens of Clarksdale, Coahoma County, have thought for some time that this tough gumbo clay could be burned and utilized for a road material. They accordingly interested the National Government in the matter and a man was sent there during the fall of 1903 to make an experiment with the clay for this purpose. The road was first graded, the center of the roadbed raised, and good ditches cut on either side. Two rows of logs 6 to 8 inches in diameter were placed on either side of the roadbed, parallel to it, and these were cross laid with good, solid, dry wood, of sufficient amount when burned to completely dehydrate the clay. Enough clay was then thrown upon the wood to make about 8 to 10 inches of clinker in the center of the roadbed. After the wood is all burned to an ash the overlying burned clay settles down on the roadbed and the road is then ready for travel.

A specimen of the unburned clay used at Clarksdale was analyzed in the laboratory of the United States Geological Survey and was found to contain 8.69 per cent of chemically combined water. A specimen of the burned clay was also analyzed and it was found to be practically dehydrated. The following are the analyses of the two clays:

*Analyses of clay used in road experiment at Clarksdale.*

| | Unburned clay. | Burned clay. |
|---|---|---|
| | *Per cent.* | *Per cent.* |
| Loss at 107° | 5.32 | 0.10 |
| Loss by ignition | 8.69 | .21 |

The road was constructed at a cost of $2,000 per mile. This included grading, fuel, and labor. After giving the road a fair test Walter Clark, of Clarksdale, asserts that it has been satisfactory. It is easier on the horses' feet and vehicles and does not get dusty or muddy. A more thorough test is now being made on another road near Clarksdale. Should the experiment prove to be successful the question of road building throughout the delta will be solved and the condition of the country greatly improved.

### METALLIFEROUS ORES.

During the progress of the present field work in Mississippi many localities were examined at which ores of gold, silver, lead, and copper were said to occur, but such examinations always resulted in failure to find even a trace of the reported metal. Occasionally masses of galenite (lead sulphide) are found at many localities in the State, but it seems certain that they were brought by the Indians from the lead district of Missouri. It is safe to say that there is practically no possibility of finding a workable deposit of gold, silver, copper, lead, zinc, or tin ores in the State of Mississippi. With regard to iron ores the case is different, but even for them the prospect is not encouraging.

### GLASS SAND AND SILICA.

An inexhaustible supply of building and molding sands is found in the Wilcox formation of northern Mississippi. Good glass sands are present at Jackson, Byram, and various other places along Pearl River (Pl. IV, *A*, p. 32).

One mile from Tennessee River, in Tishomingo County, is a large deposit of pure-white fine-grained silica. It occurs in a horizontal bed 8 to 10 feet thick. It was formerly mined for an adulterant, but its whiteness and purity render it a valuable material for making glass. Thousands of tons of it were mined without any evidence of exhaustion. The Chester sandstone in southern Tishomingo County is another source of a desirable glass sand.

### OIL AND GAS.

The development in recent years of large oil and gas bodies near the Gulf coast in Texas and Louisiana has given rise to the idea that similar bodies may be found in Mississippi. This idea is based on the assumption that geologic conditions in southern Mississippi are practically similar to those in the Beaumont and Sour Lake districts. It can be stated positively that this assumption is entirely erroneous and that no large oil pools of the Beaumont type can be expected to occur in Mississippi. If oil is found at all it must be in entirely different strata and under different geologic conditions.

Small local accumulations of oil or gas are occasionally struck in drilling wells for water, but none of commercial value have ever been encountered. Interesting but commercially unimportant flows of gas are of frequent occurrence in the Yazoo delta. The following description of such a flow is taken from the notebook of Dr. Eugene A. Smith, now State geologist of Alabama. The observation was made in 1871.

> These wells are about 1 mile from Walnut Ridge Place, in sec. 2 or 3, T. 13, R. 9 W., 100 yards or so from the line between Tps. 13 and 14. One of the jets is ignited and has been burning for three months or more. The gas issues from a tube about 2 inches in diameter, and the flame is about 3 feet long. Four of these pipes were driven down, and the record is that after passing through about 45 feet of the ordinary soft strata the tubes struck a hard substance into which no amount of driving could make them penetrate; the hammer would rebound and no impression would be made. The first tube was then drawn up and another was driven down a few yards distant, with the same result. They tried again, going about 50 yards away, and again the hard substance was reached. Again they moved 200 yards away and again the same result. It was noticed that some gas issued from the holes made by the tubes, and on applying fire the gas was ignited. The tube was left in the last well and the gas from it is now burning.

### COAL AND LIGNITE.

It can be stated with certainty and without reserve that true coal does not exist in Mississippi. At frequent intervals the newspapers report the discovery of coal deposits, but on examination the "coal" thus discovered is invariably found to be merely lignite. At the St. Louis Exposition of 1904 specimens of bituminous coal were shown in the Mississippi exhibit. These specimens, however, were not collected from any locality in Mississippi, but were sent in from mines located in Alabama, a considerable distance east of the State line.

At present the lignites of the State are of little economic importance owing to the cheapness of coal and the great abundance of wood. The vast quantities of pure lignite in the Eocene beds will doubtless be drawn on when the forests are destroyed and coal becomes scarce. But little effort has been made to test the heating qualities of the lignite. The few analyses which have been made show it to be high in carbon and comparatively low in sulphur. There is doubtless a future for the lignite in the making of producer gas.

Lignite occurs also in various localities in the lower Cretaceous. The deposits, however, are uniformly in very thin veins—too small to be mined profitably. It always occurs in connection with clays which contain lignitic matter. In fact, the black lignite-bearing clays are often mistaken for lignite. The thickest bed of lignite so far known in the lower Cretaceous occurs one-half mile east of Reedsville, Itawamba County. This bed is 20 inches thick and is comparatively free from impurities. Overlying the lignite is a band of ferruginous sandstone 3 to 4 inches thick, and over this in turn are beds of stratified sands. Underlying the lignite is a stratum of white stoneware clay. The lignite outcrops near the foot of the hills east of Tombigbee River between Fulton and Tilden. Lignite is also reported to have been struck in wells at Amory, Nettleton, Aberdeen, and numerous places along the Tuscaloosa area.

A greater or less amount of lignite is found throughout the Tertiary. The purest and thickest deposits occur in the lower and middle parts of the Eocene. In southeastern Lafayette, northern Calhoun, and southwestern Pontotoc counties outcrops of lignite are numerous, and the seams are in places thick enough to be mined. A seam 28 inches thick occurs in sec. 33, T. 9 S., R. 2 W. In a well at Paris a bed 6 feet thick is reported. Another outcrop on J. A. Head's land in sec. 11, T. 11 S., R. 2 W., shows a vein 5 feet thick. A sample from this seam was exhibited at the World's Fair at St. Louis. It is of a deep-brown color when damp, but becomes darker when dry. Unlike true bituminous coal it thoroughly disintegrates when it is exposed to the air for a few hours.

The following are analyses of lignite from Calhoun County:

*Analyses of lignite from Calhoun County.*

[By Alfred F. Brainard, of Birmingham, Ala.]

| | 1. | 2. |
|---|---|---|
| Fixed carbon | 37.320 | 34.250 |
| Volatile matter | 46.030 | 50.200 |
| Ash | 2.840 | 6.240 |
| Moisture | 13.910 | 9.310 |
| | 100.100 | 100.000 |

The town of De Kalb is near the eastern edge of the Wilcox formation. One and a half miles northeast of the town, on Sucarnochee Creek, is a deposit of lignite 3 feet thick, which outcrops a few feet above the bed of the creek. This deposit has been opened up with a view of developing the vein. A level was run 20 feet into the hill and considerable lignite was taken out. It was found to be of excellent quality and was burned in the office of the chancery clerk, S. O. Bell, at De Kalb. The following analyses were made, No. 1 by J. C. Long, and No. 2 by R. T. Pittman:

*Analyses of lignite from De Kalb.*

| | 1. | 2. |
|---|---|---|
| Fixed carbon | 41.83 | 40.80 |
| Volatile matter | 46.82 | 41.48 |
| Ash | 7.94 | 17.64 |
| Moisture | 2.13 | n.d. |
| Sulphur | 1.28 | 1.57 |
| Specific gravity | n.d. | 1.33 |

The lignite is overlain by a bed of gray clay and this by stratified red, yellow, and white sand, with occasional beds of ferruginous sandstone in the sand. On these hills there is a deposit of Lafayette that reaches in places a thickness of 20 feet, and in this there is considerable ferruginous sandstone.

One of the distinguishing features between the Tertiary lignites of Mississippi and the true coals of the Carboniferous is in the mode of occurrence. True coals are almost always overlain by beds of compact shale which forms a "roof" over the coal. The roof is of great service in timbering the mine. In the Tertiary lignites the roof of shale is always wanting. Thin bands of ferruginous sandstone overlying the lignite seams are often mistaken for the true roof.

## OCHER.

A beautiful red ocher underlying a large area east of Iuka, Tishomingo County, deserves special mention. It occurs in large bodies very similar to the white-clay deposits. It is of a pale-scarlet color, with small dark-brown specks of vegetable matter which has not changed as much as the main body; small particles of white clay also appear through it. The best exposures are found on R. F. Thorne's land, 6 miles northeast of Iuka, where it was formerly obtained and shipped for making paint, but this body has for some cause been abandoned. Other outcrops occur on Mr. Moore's place, 2 miles east-southeast of Iuka, and at Lake Como, just outside the town.

## PHOSPHATES, GREENSANDS, MARLS, AND OTHER FERTILIZERS.

Natural fertilizers occur in widely separated formations of the State. Despite the exhaustive treatise on the marls, greensands, and clays by Hilgard[a] little attention seems to have been paid to these means of improving the productiveness of the soils by the farmers of the State. Many of the cold and exhausted soils could be greatly improved and much better crops realized by the application of these natural fertilizers.

The upper portion of the Tuscaloosa and the lower portion of the Selma formations are highly impregnated with greensand, which contains more or less carbonate of lime and potash. Where these formations come to the surface they form a belt of very productive country. These greensands might be profitably used as a dressing on the exhausted lands of the Selma chalk area farther west, where there is still a large amount of carbonate of lime, but a lack of potash.

In the upper Cretaceous, particularly in the Ripley, the marls contain an average of 15 per cent of carbonate of lime and from one-half to 1 per cent of potash. The limestones of the Midway are likewise very rich in potash.

Greensand occurs in greater or less quantities throughout the Tertiary. Its presence is detected by the added fertility of the soil. In the Claiborne, Jackson, and Vicksburg formations it is present in the calcareous clays, marls, and limestones. These marls will be of great value if applied on the thin clay or loamy soils of central and southern Mississippi.

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[a] Hilgard, E. W., Geology and Agriculture of Mississippi, 1860.

The following analyses of the marls of the State are taken from Hilgard's Geology and Agriculture of Mississippi:

*Analyses of Mississippi marls.*

[By Dr. E. W. Hilgard.]

| | Clarke County. | Hinds County. | | Warren County. | Rankin County. | Carroll County. |
|---|---|---|---|---|---|---|
| | Garlands Creek. | Jackson. | Byram. | Vicksburg. | Dr. Quin's. | Shongalo. |
| Insoluble matter | 45.881 | 37.400 | 12.308 | 20.967 | 13.074 | 55.705 |
| Potash | 1.717 | .445 | .611 | .753 | .265 | 1.604 |
| Soda | .465 | .208 | .179 | .283 | .031 | .045 |
| Lime | 14.785 | 28.821 | 43.932 | 37.543 | 46.222 | .166 |
| Magnesia | 2.476 | 1.407 | 1.688 | 2.082 | .614 | 1.630 |
| Brown oxide of manganese | .403 | .......... | .......... | .......... | .067 | .......... |
| Peroxide of iron | 13.020 | 5.133 | 2.696 | 4.722 | 2.722 | 34.347 |
| Alumina | 7.751 | | | | | |
| Phosphoric acid | .327 | .256 | .224 | .135 | Trace. | Trace. |
| Sulphuric acid | .566 | .......... | 1.266 | .......... | .058 | .......... |
| Carbonic acid | 12.492 | 23.084 | 34.720 | 30.838 | 34.754 | .129 |
| Organic matter and water | .......... | 3.246 | 2.396 | 2.657 | 2.050 | 7.012 |
| | 99.883 | 100.000 | 100.020 | 99.980 | 99.857 | 100.638 |

| | Marion County. | | Franklin County. | Lowndes County. | Tippah County. | | Chickasaw County. |
|---|---|---|---|---|---|---|---|
| | Barnes. | Burnetts Bluff. | Cassady. | Waverley. | Ripley. | Wilhilite's. | Houston. |
| Insoluble matter | 77.438 | 83.691 | 49.475 | 88.702 | 62.441 | 73.410 | 35.750 |
| Potash | .709 | .827 | 1.242 | .204 | .730 | .702 | .681 |
| Soda | .101 | .268 | .152 | .190 | .272 | .......... | .197 |
| Lime | 4.800 | .793 | 13.190 | 1.351 | 7.952 | 6.315 | 20.558 |
| Magnesia | 1.248 | 1.053 | 1.825 | .723 | 1.560 | .886 | 1.366 |
| Brown oxide of manganese | .316 | .223 | .266 | .......... | .160 | .050 | .305 |
| Peroxide of iron | 2.989 | 4.394 | 5.538 | 5.598 | 11.849 | 7.055 | 4.190 |
| Alumina | 6.449 | 8.347 | 12.587 | | 5.865 | 5.888 | 9.475 |
| Phosphoric acid | .111 | .148 | .132 | .328 | .266 | .046 | .......... |
| Sulphuric acid | Trace. | .022 | .033 | .013 | .......... | .......... | 1.743 |
| Carbonic acid | 3.372 | .......... | 9.555 | .472 | 9.905 | 5.640 | 16.760 |
| Organic matter and water | 2.664 | .......... | 5.876 | 2.303 | | | 8.774 |
| | 100.197 | 99.766 | 99.871 | 99.884 | 101.000 | 99.992 | 99.799 |

## MINERAL WATERS.

Much attention has been paid to the numerous sulphur, chalybeate, and lithia waters of the State. Many of these have a wide reputation as medicinal waters. The water from Stafford Spring, near Vossburg, Jasper County, is used on the Mobile and Ohio Railroad dining cars, and is shipped to all parts of the United States. Other springs and wells, which are visited yearly by numerous health seekers and are reported as shipping water for the year 1904, are Arundel Lithia Springs, near Meridian, Lauderdale County; Browns Wells, Copiah County; Castalian Springs, near Durant, Holmes County; Rawles Spring, near Hattiesburg, Perry County; and Tallaha Springs, near Charleston, Tallahatchie County.

The mineral waters form a very important commercial product of the State. The following is the output from 1900 to 1904 inclusive:

*Production of mineral waters in Mississippi from 1900 to 1904.*

| Year. | Number of springs reporting. | Product (gallons). | Value. |
|---|---|---|---|
| 1900 | 6 | 282,228 | $48,617.00 |
| 1901 | 7 | 345,457 | 45,965.00 |
| 1902 | 7 | 459,485 | 77,868.00 |
| 1903 | 6 | 348,119 | 28,956.00 |
| 1904 | 6 | 332,131 | 60,258.00 |

Among the States and Territories of the United States Mississippi ranked in 1904 nineteenth in the quantity and sixteenth in the value of the mineral waters produced; of the southern States only three produce more than Mississippi.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

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# REPORT

ON

# GRESS OF INVESTIGATIONS OF MINERAL RESOURCES OF ALASKA

IN

# 1905

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By ALFRED H. BROOKS AND OTHERS

WASHINGTON
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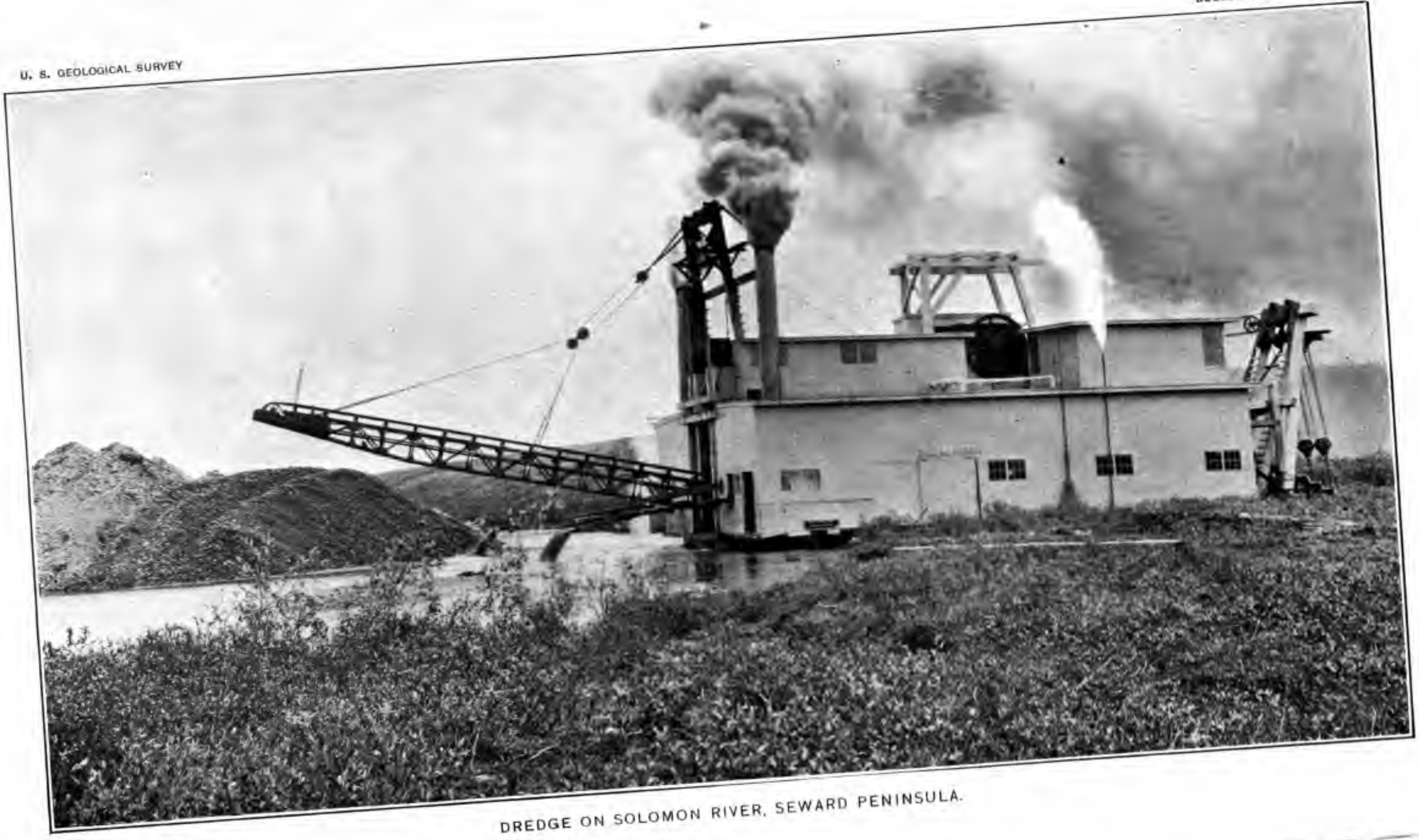

DREDGE ON SOLOMON RIVER, SEWARD PENINSULA.

# REPORT ON PROGRESS OF INVESTIGATIONS OF MINERAL RESOURCES OF ALASKA IN 1905.

By Alfred H. Brooks and others.

# ADMINISTRATIVE REPORT.

By Alfred H. Brooks.

## INTRODUCTION.

The publication last year of a volume summarizing the economic results of the field work of the Alaska division has found favor among mining men, and it has been decided to issue a similar volume every spring. Though such advance papers can often embody only tentative conclusions, it is believed that even these, when intelligently used, are of practical value to the mining industry; at least their value is much enhanced by early publication. Those who make use of this report should bear in mind its true character, and not place the same confidence in the conclusions that would be given to treatises representing more exhaustive field and laboratory studies.

As in the previous report, the papers fall into three groups—(1) summaries of progress in various phases of the mining industry during the last year; (2) preliminary accounts of investigations in progress or completed; (3) statements of the results of minor investigations not to be published elsewhere.

As the field covered is very extensive and many of the mining districts are isolated, it is impossible, with the present force of the division, to visit all the mining regions every season. The attempt has been made, however, to procure reliable information from every district, and this has been embodied in the summary statements. This has been possible only through the cordial cooperation of mining men in all parts of the Territory, to whom the writer desires to express his obligations. In the future this side of the work will be developed as fully as is commensurate with the chief objects of the investigations, namely, the mapping and study of the mineral resources of the Territory. It is hoped that, eventually, as transportation facilities improve and the work expands, it will be possible to issue an annual statement which will summarize concisely and authoritatively the advance of the mining industry throughout the Territory.

As in the previous report the notes on placer-mining operations naturally occupy more space than any other part of the subject, since the placer mines are still the largest producers. The field investigation of placers in 1905 has been practically limited to the Yukon basin and Seward Peninsula, and as these are also the largest producers they are treated at greater length than the other alluvial gold-bearing regions.

The volume contains 15 different papers by 13 different authors. Promptness of publication necessitates the elimination of all illustrations except a few of the simplest. The more complete reports with full illustrations will be issued as soon as possible.

## PROGRESS OF SURVEYS.

As in 1904, nine parties were engaged in field work during the open season, which lasted from about May 15 to October 15. Several of these were subdivided after reaching Alaska, making in all fourteen parties at work for a whole or a part of the season. The technical force of these parties, including geologists, topographers, and assistants, aggregates 23 men, in addition to which 28 camp men, etc., were employed. Of the fourteen parties, eight were engaged in geologic investigations, five in topographic surveys, and one combined both classes of work.

The geologic work included a continuation of the reconnaissances of southeastern Alaska and the Yukon-Tanana region, and examinations of the Yakutat Bay, Matanuska Valley, and Prince William Sound regions. Detailed surveys were made in the Controller Bay and Nome regions. Topographic reconnaissance surveys aggregating about 4,500 square miles were made in the Yukon-Tanana and Controller Bay regions. Detailed topographic surveys of areas aggregating 900 square miles were made in the Seward Peninsula and Controller Bay regions.

*General.*—A large portion of the time of the geologist in charge was given to administrative work. With the aid of the members of the division, attempt was made to keep in close touch with the developments in the mining industry throughout the Territory. This task becomes increasingly difficult each year because of the rapid expansion of the mining interests. As far as possible a member of the staff is sent to each district every year, but where this is impossible, information in regard to new developments is obtained by correspondence.

The writer has devoted such time as could be spared from administrative work to a continuation of his report on the Mount McKinley region and also to the preparation of chapters on the economic geology and history of mining, to be included in a report by Arthur J. Collier on the gold placers of Seward Peninsula. The months of June and July were devoted to field work in the Controller Bay region in company with Mr. Martin and to a reconnaissance of Portland Canal in company with Mr. Wright.

*Southeastern Alaska.*—The work in southeastern Alaska was continued in charge of Fred E. Wright, assisted by C. W. Wright. E. M. Kindle spent about two months in this district in paleontologic work and rendered valuable aid in the deciphering of the stratigraphy. The reconnaissance mapping was carried southward from the Juneau district and extended over the greater part of the Wrangell and Ketchikan mining districts. Special attention was given to a study of the gold and copper deposits of this field. The preliminary results are embodied in the following pages and a more comprehensive statement of the economic geology of this field is in preparation.

*Yakutat Bay.*—R. S. Tarr, assisted by B. S. Butler and Lawrence Martin, studied the geology of the Yakutat Bay field. He gave special attention to the question of the occurrence of coal and also to the source of the gold now found in small quantities in the beach placers. The important conclusions are embodied in the following pages.

*Controller Bay.*—A party under the leadership of G. C. Martin mapped the geology and topography of the Controller Bay petroleum- and coal-bearing rocks. E. G. Hamilton, assisted by W. R. Hill, carried a topographic survey on a scale of 1:45,000 over an area of 430 square miles and made a reconnaissance survey of an additional area of about 200 square miles. Mr. Martin, assisted by A. G. Maddren, and for a part of the season by Sidney Paige, made an investigation of the geology and mineral resources of the same area. A report on the results of this work is in preparation, but an account of some of the more important conclusions is given in this volume.

*Prince William Sound.*—U. S. Grant, assisted by Sidney Paige, spent about two months in studying the geology and mineral resources of the Prince William Sound region. Special attention was given to the copper deposits. Some preliminary notes on the results of their investigations accompany this report. The complete report is in preparation.

*Cook Inlet.*—G. C. Martin also made a reconnassiance of a part of the Matanuska coal field, lying 30 miles northeast of Cook Inlet. His report is in preparation, but the more important conclusions bearing on the economic geology are incorporated in this volume.

*Southwestern Alaska.*—Incidental to his other field work Sidney Paige spent a few days at Herendeen Bay examining some of its coal fields and submits the accompanying report.

*Seward Peninsula.*—Fred H. Moffit and Frank L. Hess mapped the areal geology of about half of the area covered by the Nome and Grand Central special maps. The geology was found to be unusually intricate, and this fact, together with the detailed studies of the auriferous gravels, made the progress of mapping very slow. A supplementary study of some of the tin deposits of the York region was made by Mr. Hess, and the results are here presented.

T. G. Gerdine, assisted by W. B. Corse and B. A. Yoder, made a topographic survey (1:45,000) of 470 square miles in the Solomon and Casadepaga regions.

*Yukon-Tanana region.*—Geologic reconnaissance mapping was continued in the Yukon-Tanana field by L. M. Prindle, assisted by Adolph Knopf. The work was carried from the international boundary, near the head of Sixtymile River, south and west to Fairbanks.

D. C. Witherspoon, assisted by R. B. Oliver, mapped on a scale of 1:250,000, 4,300 square miles in a region lying between Circle, Fairbanks, and Fort Hamlin. It is believed that the topographic reconnaissance mapping of this field can be completed in two more seasons.

# THE MINING INDUSTRY IN 1905.

By Alfred H. Brooks.

## INTRODUCTION.

The advancement of the mining industry in Alaska during the past decade is attested by the increase of the value of its annual output from less than $2,400,000 in 1895 to over $15,000,000 in 1905. The gold production of 1905 showed an increase of probably 60 per cent over that of 1904, and probably over 90 per cent of this increase came from the Fairbanks placers. Nearly all the other districts, except some in the Seward Peninsula, increased their output. In the following table the general distribution of the gold output is indicated. There are no exact figures available, but the table is based on the most reliable data. Under the heading "Pacific coastal belt" is included the output of the lodes and placer mines of southeastern Alaska and of the bench diggings to the east, as well as that of the Apollo Consolidated on Unga Island. The production of the Sunrise district of Cook Inlet and of the Copper River district are grouped together and come entirely from placers. In the Yukon basin are included the Fortymile, Birch Creek, Fairbanks, Rampart, and Koyukuk placer districts. The output of Seward Peninsula is practically all from placers, though one lode mine has been in operation for several years. The estimate of the output for 1905 is based on the data gathered by the field parties of the Geological Survey, as the statistics from the mint are not yet available.

*Gold production of Alaska, with approximate distribution.*

| Year. | Pacific coastal belt. | Copper River and Cook Inlet region. | Yukon basin. | Seward Peninsula. | Total.[a] |
|---|---|---|---|---|---|
| 1880 | $20,000 | | | | $20,000 |
| 1881 | 40,000 | | | | 40,000 |
| 1882 | 150,000 | | | | 150,000 |
| 1883 | 300,000 | | $1,000 | | 301,000 |
| 1884 | 200,000 | | 1,000 | | 201,000 |
| 1885 | 275,000 | | 25,000 | | 300,000 |
| 1886 | 416,000 | | 30,000 | | 446,000 |
| 1887 | 645,000 | | 30,000 | | 675,000 |
| 1888 | 815,000 | | 35,000 | | 850,000 |
| 1889 | 860,000 | | 40,000 | | 900,000 |
| 1890 | 712,000 | | 50,000 | | 762,000 |
| 1891 | 800,000 | | 100,000 | | 900,000 |
| 1892 | 970,000 | | 110,000 | | 1,080,000 |
| 1893 | 838,000 | | 200,000 | | 1,038,000 |
| 1894 | 882,000 | | 400,000 | | 1,282,000 |
| 1895 | 1,569,500 | $50,000 | 709,000 | | 2,328,000 |
| 1896 | 1,941,000 | 120,000 | 800,000 | | 2,861,000 |
| 1897 | 1,799,500 | 175,000 | 450,000 | $15,000 | 2,439,500 |
| 1898 | 1,892,000 | 150,000 | 400,000 | 75,000 | 2,517,000 |
| 1899 | 2,152,000 | 150,000 | 500,000 | 2,800,000 | 5,602,000 |
| 1900 | 2,606,000 | 160,000 | 650,000 | 4,750,000 | 8,166,000 |
| 1901 | 2,072,000 | 180,000 | 550,000 | 4,130,700 | 6,932,700 |
| 1902 | 2,546,600 | 375,000 | 800,000 | 4,561,800 | 8,283,400 |
| 1903 | 2,843,000 | 375,000 | 1,000,000 | 4,465,600 | 8,683,600 |
| 1904 | 3,195,800 | 500,000 | 1,300,000 | 4,164,600 | 9,160,400 |
| 1905 | 3,400,000 | 500,000 | 6,800,000 | 4,500,000 | [b] 15,200,000 |
| | 33,940,400 | 2,735,000 | 14,981,000 | 29,462,700 | 81,118,600 |

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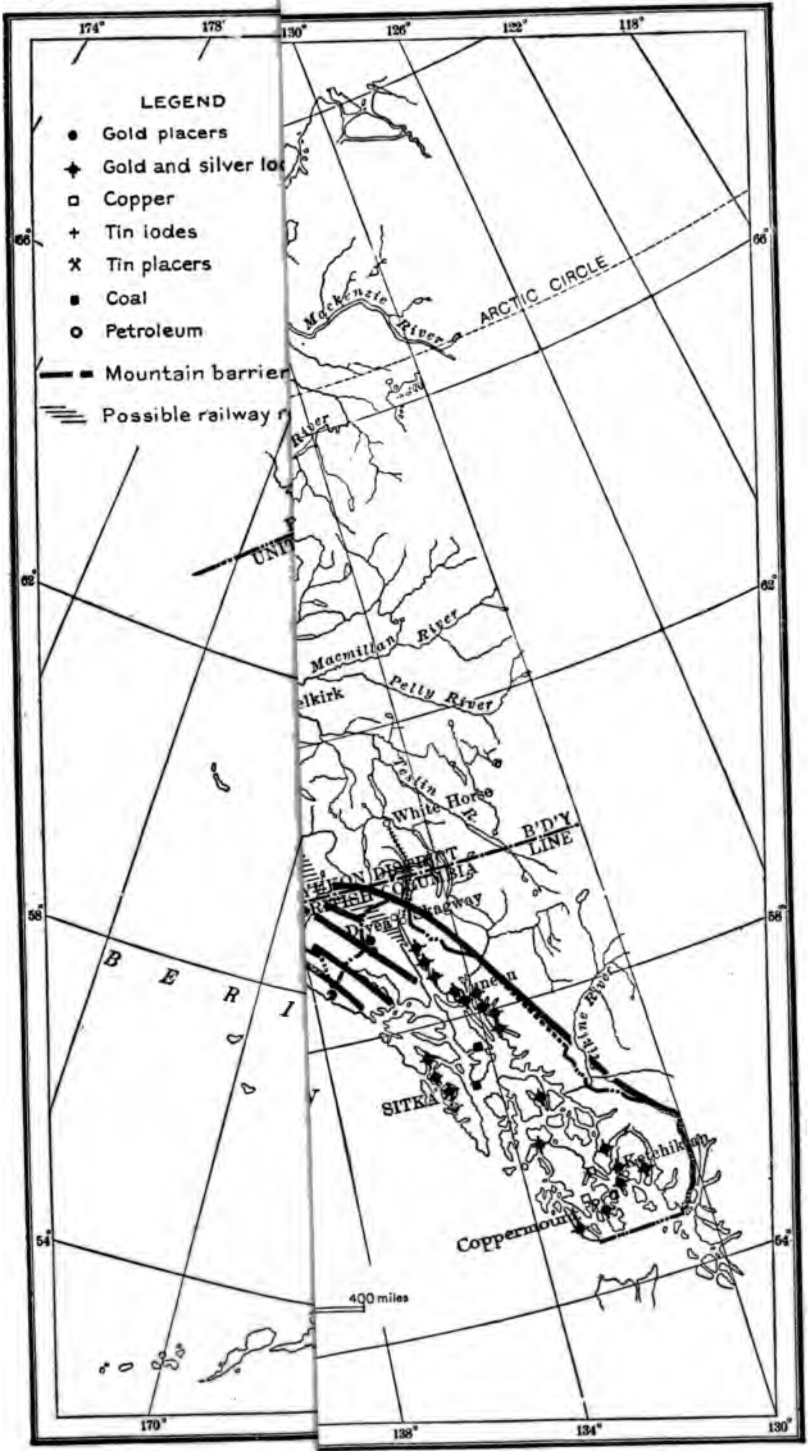
[a] Based on reports of the Director of the Mint, except for 1905. [b] Estimated by Alfred H. Brooks.



MRTANT MINERALS.

A less evident though equally important factor in this advancement is the great reduction in mining costs which has taken place during this period. The pioneer miners of the Yukon could not afford to handle gravel averaging less than $10 or $15 to the cubic yard. In the same district good wages can now be made, even by crude methods, in extracting gold from pay streak averaging less than $5 to the cubic yard. In Seward Peninsula gravels running less than $2 to the cubic yard can in many localities be handled at a profit by the man working only with the pick and shovel. In some of the interior districts, and in parts of Seward Peninsula, even present costs can be reduced to less than 50 cents to the cubic yard by introducing machinery or the use of water under pressure. Nor is there reason to believe that the latter is the limit in the reduction of costs. In lode mining the reduction of costs has been analogous, though not by any means as striking, nor are exact general figures available. Thus it is made evident that the prosperity of the mining industry must be measured not only by the increase of output, but also by the increase in net returns from mining ventures.

The value of the copper-ore production has shown a very marked increase, the total shipments of copper ore in 1905 being more than double those in 1904. This will bring the value of the annual copper production of Alaska up to over $600,000. The annual production of silver incidental to mining for other ores is about $100,000.

Work has continued on the tin deposits, but these are not yet on a productive basis. The coal fields, though extensive, have been but little exploited, the entire production for 1905 being probably less than 2,000 tons. Prospecting for coal has been very active in the Controller Bay region and in the Matanuska Valley. The only other developed mining industry is marble quarrying, which, according to the returns of the customs officials, has shown an exported production of about $3,000 in value.

Notable advances have been made in three mining regions, and practically all the others have shown a healthy growth. In southeastern Alaska the copper deposits of Prince of Wales Island have reached a productive stage, and auriferous lode mining in the Juneau district has made considerable progress. The two copper mines on Prince William Sound have considerably increased their output, and much was done in the way of prospecting other properties. By far the most important feature of the last year is the rapid expansion of the placer-mining industry of the Fairbanks district in the Tanana Valley. This field produced more than ten times as much gold in 1905 as in 1904.

In the following pages an attempt will be made to review briefly the progress during the year. The important districts, described elsewhere in this volume, need only be mentioned briefly, but some of the less productive fields, not considered elsewhere, will be treated of in such detail as the available information permits.

## DISTRIBUTION OF MINERAL WEALTH.

The map (Pl. II) shows the distribution of the known localities of occurrence of economically important minerals. Three broad belts, which are the loci of the gold deposits, are recognizable. One stretches parallel to the Pacific seaboard through the panhandle of the Territory, and, following the great bend of the coast line, is lost among the islands of southwestern Alaska. This zone includes practically all the auriferous-quartz mines of the Territory and also some of the smaller placer districts. In this same general belt also lie the copper deposits of Prince of Wales Island and Prince William Sound. A second belt extends northwestward from the international boundary near the famous Klondike. It includes much of the region lying between the Yukon and the Tanana, thence it probably bends to the southwest and extends into the area drained by the Kantishna. This zone has thus far yielded only placer gold. The third and less-known belt includes the placer district of the upper Koyukuk, west of which it is mantled by younger sediments. The gold placers of Kobuk River and Seward Peninsula may represent a southwesterly extension of this same belt, but the connection between the two has not been established. This third zone has thus far produced only placer gold, with the exception of a single quartz mine on Seward Peninsula.

As will be shown below, the gold-bearing terranes of southeastern Alaska are made up of metamorphic rocks, chiefly of Permian age; those of the Yukon are of undetermined, probably Lower Paleozoic age, while the terranes of Seward Peninsula find place in the Silurian or in older sediments. In all these districts there appears to be a rather intimate connection between the occurrence of the quartz veins, whence the gold has been derived, and the intrusives. If the very incomplete data should permit one to venture an opinion, it would be that the period of mineralization in both the coastal and the Yukon provinces occurred during Lower Cretaceous time. In Seward Peninsula the mineralization may have taken place at a later date. The copper deposits of the Mount Wrangell region, associated with rocks of Permian age, appear to be the result of a distinct type of mineralization not yet found elsewhere in Alaska.

Coal-bearing strata, chiefly of Eocene or Oligocene age, find a wide distribution throughout Alaska. Both Carboniferous and Jurassic coal measures have been found at Cape Lisburne. The most extensive coal fields of the Territory probably lie in the Arctic slope region, but those of the Pacific seaboard and the Yukon River basin are of the most importance. The high-grade bituminous coals of the Controller Bay region and of the Matanuska Valley, described elsewhere in this bulletin, are at present of the most commercial importance. Good coal has also been found in the Alaska Peninsula, but the extent of the deposits has not been determined.

## AURIFEROUS LODE MINING.

Southeastern Alaska continues to be the only important district of lode mining in the Territory, but considerable prospecting has been done in other fields. The Panhandle, with its strong relief, abundant water power and timber, accessibility, and salubrious climate is undoubtedly the ideal mining region of Alaska and compares favorably with any other on the continent. The success of the famous Treadwell group of mines is an example of what can be accomplished in this field under scientific management. This great enterprise, though a magnificent object lesson, has dwarfed other important plants in the same field. It has also led to the inauguration of a number of unsuccessful ventures, because promoters have been only too ready to designate every low-grade ore body as "another Treadwell." The auriferous lode mining of this part of Alaska is fully described by F. E. Wright and C. W. Wright on pages 30–54.

Westward from the Panhandle there is no lode mining until Prince William Sound is reached. The copper deposits of this district are described by Mr. Grant (see p. 78). These ore bodies carry more or less gold, and hence deserve a passing mention here. The Kenai Peninsula has been the scene of considerable prospecting for quartz during the past year. Some encouraging results are reported near the line of the Alaska Central Railway and also at Port Dick and Port Chatham, near the extreme south end of the peninsula. Copper- and gold-bearing lodes have also been found on the west side of Cook Inlet, near Iliamna Bay, but their commercial importance remains to be proved.

Kodiak Island has been the scene of prospecting for quite a number of years, but so far no extensive ore bodies have been found there. Mr. Paige, who visited some points on this island during the past summer, reports that the bed rock consists primarily of slates and sandstones, with some conglomerate. The entire rock series is closely folded and jointed and is cut by an intricate system of quartz stringers. These stringers, in some cases, are large enough to be called veins and carry some sulphides and are probably the source of the beach gold which has been mined at several localities. A five-stamp mill has been at work at Uyak Bay, on the west side of the island, for several years. In the extreme southwestern portion of Alaska lode mining is on the decline, for the Apollo Consolidated mine, which has been operated on Unga Island for many years, has been closed down.

The Yukon region, though it continues to be the scene of extensive gold-placer discoveries, so far has not yielded any auriferous lodes. The same holds true in Seward Peninsula, where, with the exception of the Big Hurrah quartz mine, no lode deposits have been developed. It is to be said for both these fields, however, that but little attention has thus far been given to prospecting for auriferous veins. It is probably true that a large part of the gold placers have been concentrated from the gold contained in disseminated quartz veins, but there is, nevertheless, the possibility that workable lode deposits may yet be found.

## GOLD PLACERS.

As already stated, the most important development in the placer fields has taken place in the Fairbanks district, which produced over half the placer-gold output of the Territory for 1905. Seward Peninsula was, however, also a large producer, and smaller amounts were recovered in southeastern Alaska and the Copper River-Cook Inlet region. The Porcupine district leads in the placer-gold production of southeastern Alaska, though there is some output from the Juneau district. Beach mining still continues along the Pacific coast westward from Lituya Bay. This gold, which appears to be the result of wave concentration from glacial deposits, has not been found in sufficient amount to warrant exploitation in any but a small way. The entire product of the beach mining, embracing the Pacific seaboard of Alaska, is probably between $50,000 and $100,000 per year.

Operations continue in the Copper River basin in spite of the fact that the very high cost of transportation makes mining exceedingly expensive. Two districts are producing placer gold—the Nizina, where a number of claims were in operation during the past year, and the Chisana, where mining was also active. The output of this field for 1905 is estimated at $300,000.

The northern part of the Kenai Peninsula has produced placer gold for twelve years. During this period there has been a steady growth of the mining industry and a proportionate increase in the annual output, which is now estimated at about $200,000. The extensive gravel deposits, steep gradients, and abundant water supply make this field eminently suitable for hydraulic mining. According to Mr. H. H. Hildreth, United States commissioner at Seward, the completion of several hydraulic plants is the most important development during the past season.

Gold is also reported from the western tributaries of the lower Sushitna which head in the Alaska Range. C. W. Purington reports that gold has been discovered on Peters Creek, a tributary of the Kahiltna, which flows into Chulitna River. The gravels are said to be not over 5 to 7 feet in depth, and the diggings are reported to yield from $10 to $20 to the man. It is said that about 200 men visited this district last year and that 75 are wintering there. A small hydraulic plant has been at work on Willow Creek, an easterly tributary of the Sushitna, and a small amount of gold produced. Some auriferous gravels are also reported from other parts of the Sushitna basin, though no values have been found that would yield returns under present conditions.

The Yukon region is described in detail by Prindle elsewhere in this report (pp. 109–127) and need not be dwelt on here. While the interest of mining men has been concentrated on the Fairbanks district, other fields have received some attention. Of special interest is the development of some placers on Salcha River, indicating a wider distribution of the workable placers than previously known. Of still greater interest is the reported strike of very rich gravels southwest of the Tanana in the Kantishna Valley. This would seem to indicate that the gold belt turns to the southwest, and at least suggests that the gold reported in the Innoko River basin may be derived from a continuation of the same belt of rocks.

The production of Seward Peninsula has not shown the increase expected by some. This is largely because, as shown by Mr. Moffit (pp. 132–144) much of the attention of mining men was given to dead work and also because of an unfavorable season. There can be no doubt that within the next few years there will be a very large increase in the output of the peninsula. Gold has been reported from tributaries of Norton Bay for some years, but only recently has it been produced from this district in commercial quantities. It is reported that claims have been worked on Bonanza Creek, a tributary of the Inglutalik, which enters Norton Bay from the east. These claims have been worked since 1900 by means of a small pumping plant. Nuggets worth from $5 to $10 have been found. The stream gradients in this field are very low, which increases the cost of mining.

Mining continues in the Kobuk River region, in the northern part of Alaska, 4 claims having been worked in 1905 according to Mr. M. F. Moran. The shortness of the season and the high cost of provisions have made it impossible to work anything but the very richest claims. It is said that unless a claim pays more than $10 a day to the man, it can not be developed. A little placer gold, estimated at $5,000 in 1905, has been produced in this field, but most of the miners have left the region.

## COPPER.

In 1905 there were two copper-producing districts, Ketchikan and Prince William Sound, and in three more, the Chitina (Copper River basin), White-Tanana, and Kenai districts, considerable prospecting was done. Copper has also been found in other parts of southeastern Alaska and reported from a field lying immediately west of Cook Inlet. The copper deposits of Prince of Wales Island and of Prince William Sound are described on pages 46–53 and 78–87. Their rapid development, as compared with that of the inland districts, is due to their proximity to tide water, open to navigation throughout the year. Two smelters have been completed on Prince of Wales Island, but the bulk of the Alaska ores are still shipped to Tacoma.

In the Chitina district prospecting is steadily progressing on the copper properties lying on the southern slope of the Wrangell Mountains. At present this field is reached only after a 200-mile journey over a rough trail. Freight charges to the district are as high as a dollar a pound in summer and 15 to 20 cents a pound in winter. In spite of this excessive cost, considerable development work has been done in the district. The general features of the geology have been described in previous reports by the Geological Survey[a] in which it has been shown that the copper deposits occur at or near the contact of an extensive series of ancient lavas and a white crystalline limestone. The latter is probably of Permian age. The ores found in place are chiefly sulphide, for the native copper, occurring in the gravels near the east end of the field, has not been traced to its bed-rock source. The results of the prospecting of the last two years indicate a greater persistency at depth than was expected from the surface croppings. At the east end of the field a vein has been followed to a depth of about a hundred feet, and a lode near the west end of the field has been tested by diamond drilling to a depth of about 50 feet. The reported results of this prospecting indicate a permanence of the ore bodies which augurs well for the development of an important copper district. Further operations must await the construction of a railway from the coast.

A second, less-known copper belt lies north of the Wrangell Mountains, stretching westward from the international boundary, at the head of White River, to the headwater basins of Tanana River. These ore bodies are closely associated with greenstones and limestones, but their form of occurrence is less well known than in the case of the southern field. The reports of the prospecting of the past year warrant a further investigation of this belt. The permanent development of this field can be accomplished only with the aid of railway facilities, but the fact that water transportation is available within 50 miles of any point in the district is of the greatest possible importance, and this was demonstrated last year by Mr. Henry Bratanober, who took a small steamer up the Tanana to the mouth of the Nabesna.

Mention should be made of the occurrence of lodes carrying copper sulphide in the Kenai Peninsula. Little is known of the character of these deposits, but they appear to lie in a southwesterly extension of the belt of metamorphic rocks which carry copper in the Prince William Sound region. Work on these deposits has been stimulated by the construction of the Alaska Central Railway.

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[a] Schrader, F. C., and Spencer, Arthur C., The Geology and Mineral Resources of a Part of the Copper River District; special pub. U. S. Geol. Survey, 1901. Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: Prof. Paper U. S. Geol. Survey No. 15, 1903.

## COAL.

The coal fields of Alaska still remain practically undeveloped, and most of them must await the construction of railways before their product can be marketed. Much prospecting was, however, done, notably in the Controller Bay and Matanuska fields, which are described by Mr. Martin on pages 65–77 and 88–100. Interest in the coal fields has been stimulated by the surveys of several railway routes in the Controller Bay field and by construction work on the Alaska Central Railway, which will tap the Matanuska field. A little coal for local use was mined in the Cook Inlet region, on lower Yukon River, and in Seward Peninsula. These operations were mostly confined to lignitic or to low-grade bituminous coals.

## LESSER MINERALS.

Mr. Wright presents a statement (pp. 55–60) on the nonmetallic resources of southeastern Alaska, including granite, marble, gypsum, and mineral water. Of these only the marble and mineral water have been developed. The marble industry promises well. Though there is quite likely to be marble found in other parts of the Territory, unless it be on the Pacific tide water it can have only very remote value. The mineral waters of the Panhandle are being bottled on a small scale for local use. The developments of the tin ores are fully treated elsewhere by Mr. Hess (pp. 145–157). Some prospecting of the cinnabar deposits on the lower Kuskokwim has been done.[a]

But little progress has been made in the search for oil pools. During the season of 1905 four rigs have been drilling for petroleum in Alaska—two at Controller Bay, one at Cook Inlet, and one at Cold Bay. Members of the Survey have visited only the wells on Controller Bay, neither of which have, up to date, proved successful.

The outcome of all the drilling in Alaska has shown that very complete and first-class outfits are necessary; and because of this and of the other unfavorable circumstances, such as shortness of the season, high freights and wages, and remoteness from labor, supplies, and repair shops, drilling has proved extremely expensive. One of the important factors to consider in this northern region is whether even successful wells will justify the great drilling and operating costs, in competition with the more favorably situated fields to the south.

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[a] Spurr, J. E., A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 261-262.

# RAILWAY ROUTES.

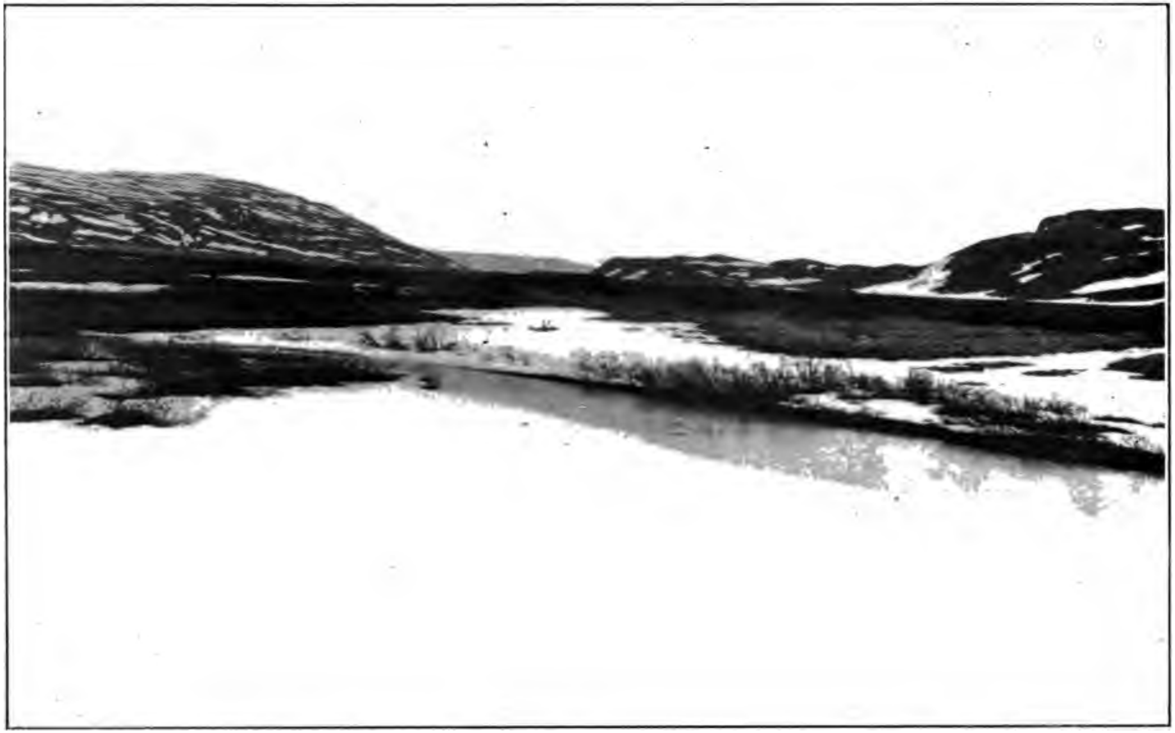
By Alfred H. Brooks.

## INTRODUCTION.

The past decade has witnessed tremendous strides in the commercial advancement of Alaska, but the development of means of transportation has not kept pace with the demands of the mining interests. Though the coastal transportation system is greatly improved over what it was a few years ago, and many steamers ply on the waterways of the Yukon basin, these do not adequately meet the requirements of the many inland mining districts. The improved steamboat service and the few miles of railway in operation only serve to emphasize the necessity of a complete revolution of the entire transportation system for a full development of the resources of the Territory. Under the present conditions freight for the Yukon camps must be transshipped several times, and its transportation from the coast inland can take place only during the summer months. Nor is this all, for after the freight has been carried as near to its destination as possible by steamer it must then usually await the winter snows before it is sledded for 20 to 100 miles to the placer mine. In the Copper River region the conditions are still worse, for there all freight has to be sledded inland from the Pacific coast for a distance of 200 to 250 miles, at a cost of 15 to 25 cents a pound. In summer emergency supplies are brought into this district on pack horses, at a cost of 50 cents to $1 a pound. In southeastern Alaska and on Prince William Sound mining is practically confined to the actual shore line. The few properties which lie away from the coast have been developed by wagon roads or tramways, usually not many miles in length. In Seward Peninsula the transportation problem is less acute than in the Yukon basin, for during a dry season much of its surface can be traversed in wagons. Moreover, a number of short railways have been built which have materially aided the mining development.

The pioneer prospector on the Yukon, equipped with his shovel, pick, gold pan, whipsaw, and ax, transported by raft or canoe along the water courses and on his own back for overland journeys, carried on his mining ventures without the aid of any transportation system except that of his initiation. With such simple tools many millions of dollars have been won from the gravels, and even to-day there are a number of placer districts whose yield is largely dependent on almost the same primitive methods. The enormous increase in the placer-gold output of the last two years must, however, be credited to the improvement of methods by the introduction of machinery. These improvements have been brought about in spite of the enormous transportation charges, to which must be added the cost of unavoidable delays. These expenses represent a direct tax on the mining industry, and make it now impossible to exploit many placers which could be made to yield a handsome profit if they were made more accessible by the construction of railways supplemented by wagon roads. This is still more striking in the case of lode and coal mining, for this industry must await railway construction unless the deposits are on navigable waters.

It is only within a few years that the mineral resources of Alaska have become sufficiently well known to attract capital, and there is still much conservatism regarding the possibilities of this field for investment. Though there is abundant opportunity for the individual prospector of small resources, but of determination and experience, yet the time is ripe for larger ventures which can be handled only by considerable investments. This fact



DIVIDE AT HEAD OF THE CHILKAT; RAILWAY ROUTE, LYNN CANAL TO FAIRBANKS.

*A*. TATSHENSHINI VALLEY (EAST FORK OF THE ALSEK); RAILWAY ROUTE, LYNN CANAL TO FAIRBANKS.

*B*. ABANDONED VALLEY IN WHITE RIVER BASIN; RAILWAY ROUTE, LYNN CANAL TO FAIRBANKS.

Donjek River in foreground.

has been recognized in the Seward Peninsula, but the gold and copper fields of the interior have received relatively little attention, largely because of the absence of means of communication. An adequate transportation system, involving the construction of railways, is then the first requisite for more rapid advancement.

To speak broadly, there are three provinces in inland Alaska of whose resources there appears to be sufficient knowledge to warrant the construction of railways, namely, the Yukon-Tanana region, the Copper River basin, and the Sushitna River basin. The first produced about $7,000,000 in placer gold last year and includes large areas of auriferous gravels which could be exploited if costs were lessened. In the Copper River basin there are valuable copper deposits and some placer districts. The Sushitna basin includes an important coal field as well as some placer deposits, and also more arable land than any areas of similar extent in the Territory. Railways, to aid the development of the resources of these districts, must be built inland from good and accessible harbors on the Pacific and follow one of the natural highways through the coastal mountains.

## GEOGRAPHIC CONTROL OF ROUTES.

A rugged mountain mass (see Pl. II) fringing the coast line of British Columbia and stretching northward into Alaska, presents along thousands of miles of the Pacific seaboard a serious barrier to inland travel. This, however, is broken by a number of transverse valleys and low passes which form the natural highways into the interior. Beyond the coastal mountains lies a province of lesser relief, which presents but few obstacles to railway or road construction, and which continues eastward and northward to another mountain barrier, a northwesterly extention of the Rocky Mountain system. The Pacific coastal mountains, represented by a single range 50 to 80 miles in width along the boundary of British Columbia and Alaska, broaden out as they enter the Territory, reaching an extreme width of 200 miles, and being there made up of a number of parallel ranges. Through this series of ranges the railway engineer who desires to tap the mineral resources of inland Alaska must seek a route.

For the purposes here considered the coastal termination of an inland railway must fall between Lynn Canal on the east and Cook Inlet on the west. Furthermore, the geographic features limit the routes to four zones, which may be defined as (1) the Chilkat basin, (2) the Alsek basin, (3) the Copper basin, and (4) the Sushitna basin. Within most of these general zones there are a number of alternative routes, but in general terms the best routes follow the trunk streams mentioned above. These routes will be discussed in their geographic order from south to north.

## LYNN CANAL AND TANANA VALLEY ROUTE.[a]

Chilkat River debouches into a western arm of Lynn Canal called "Pyramid Harbor," and its valley separates the St. Elias Range on the west from the Coast Range on the east. Its headwaters are separated from inland flowing streams by broad passes about 3,300 feet high 50 miles from the coast. (Pl. III.) From the Chilkat Valley the route would enter the Alsek basin (Pl. IV, *A*), following the inland front of the St. Elias Range. Two forks of the Alsek will have to be crossed, but present no engineering difficulties. Beyond the west fork of the Alsek the line would follow a series of depressions which represent abandoned valleys and afford ideal railway routes. (Pl. IV, *B*). It would skirt the south shore of Lake Kluane 2,400 feet above sea level and enter the White River Valley near the international boundary. After crossing White River at the canyon the line would be extended through a broad flat depression to the Tanana Valley, which would be followed to Fairbanks. (Pl. V.) Branch lines not exceeding 30 miles in length could be built to the copper deposits on the heads of the White and the two sources of the Tanana. A branch to Eagle, which would tap the Fortymile placer district, would be about 160 miles in length. From Fairbanks the Birch

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[a] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 331-391.

Creek and Rampart regions could be easily reached by railways. A logical continuation of the Pyramid Harbor-Fairbanks railway would be to extend it across the Yukon and thence westward to Seward Peninsula, a distance of about 600 miles. A trunk line about 1,500 miles in length, with feeders aggregating possibly 500 miles, would give access to a large part of central Alaska. The following table presents approximate distances and altitudes along this route:

*Elevations and distances, railway route from Pyramid Harbor to Fairbanks by way of the head of White River.*

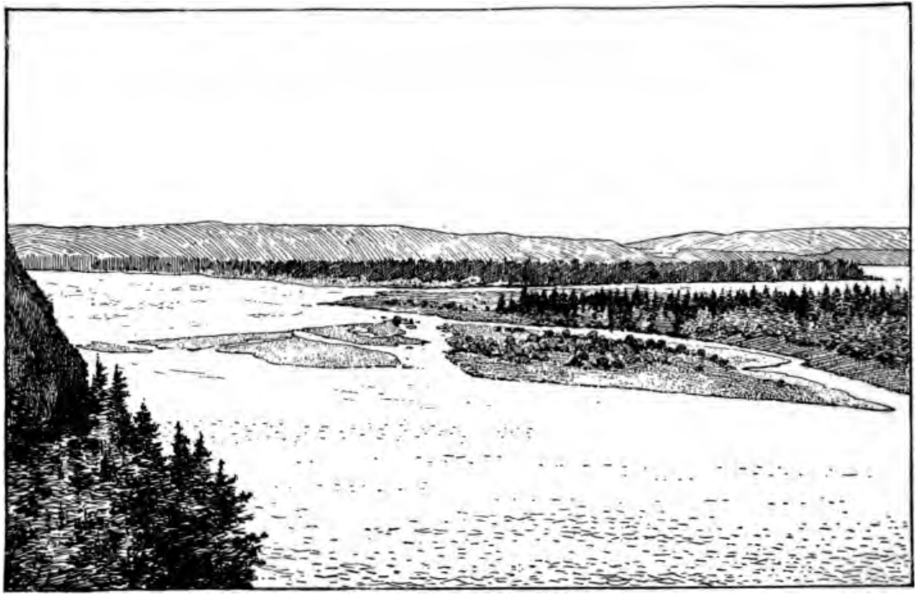
| Point. | Elevation. | Distance between points. | Distance from Pyramid Harbor. |
|---|---|---|---|
| | *Feet.* | *Miles.* | *Miles.* |
| Pyramid Harbor | 0 | 0 | 0 |
| Klehini River | 0 | 60 | 60 |
| Pass | 3,250 | 40 | 100 |
| Dalton Post | 2,520 | 30 | 130 |
| Alsek River | 2,000 | 60 | 190 |
| Upper end of Lake Kluane | 2,400 | 60 | 250 |
| Lower end of Lake Kluane | 2,400 | 60 | 310 |
| Donjek River | 2,500 | 50 | 360 |
| White River Canyon | 2,400 | 60 | 420 |
| Chisana River | 2,200 | 70 | 490 |
| Mouth of Nabesna River | 2,000 | 45 | 535 |
| Tanana crossing | 1,900 | 55 | 590 |
| Goodpaster River | 700 | 105 | 695 |
| Salcha River | 550 | 55 | 750 |
| Fairbanks | 490 | 50 | 800 |

Pyramid Harbor, which affords shelter for vessels and opportunities for wharf construction, can be reached by a 1,000-mile journey from Puget Sound, entirely within sheltered waterways. The Chilkat basin is well timbered (chiefly spruce and hemlock) and contains some auriferous gravels, though the producing district lies somewhat off the proposed railway route. The copper deposits of Rainy Hollow, which are undeveloped, lie about 20 miles off the main route. In the inland region there are no developed mineral resources until Lake Kluane is reached, where there is a small placer district. It is to be borne in mind, however, that what little is known of this region indicates that there may be here a continuation of the mineralized belt of southeastern Alaska, which makes it possible that workable ore deposits may yet be found. The copper belt of the upper White and Tanana basins, also on this route, is entirely undeveloped, but the outlook for finding values is encouraging. The placer districts of the Yukon-Tanana region have already been referred to. The Tanana and Alsek basins are timbered with spruce and contain also considerable grazing and agricultural land.

There can be no doubt that this is the natural route into the interior, and it was long used by the natives in their intertribal intercourse. It has one grave disadvantage, namely, that for about 300 miles it traverses Canadian territory and would therefore not afford an all-Alaskan route. Moreover, it would not help to develop the resources of the Copper River and Sushitna River basins.

## YAKUTAT BAY-ALSEK ROUTE.

The lower Alsek River Valley is transverse to the St. Elias Range, and has been proposed as a route into the interior. (Pl. II.) The line would run southeastward from Yakutat Bay for about 50 miles to the mouth of the Alsek. A narrow-gage railway has already been built for about 10 miles of this distance for the purpose of bringing fish to the salmon can-



*A.* TANANA VALLEY, 50 MILES FROM FAIRBANKS; RAILWAY ROUTE, LYNN CANAL TO FAIRBANKS.

*B.* COPPER RIVER VALLEY AT COPPER CENTER; RAILWAY ROUTE, CORDOVA BAY TO EAGLE.

nery at Yakutat. The Alsek Valley is almost unexplored, but no doubt a railway could be built through it. It would intersect the Pyramid Harbor-Tanana route about 200 miles from the coast and would there attain an altitude of about 2,400 feet.

Yakutat Bay, which is about 1,150 statute miles (1,000 nautical miles) by sea from Puget Sound, is but an indifferent harbor and, so far as known, the proposed railway would not tap any mineral deposits, though such may exist in the unexplored St. Elias Mountains. It is open to the same objection as the Pyramid Harbor route, inasmuch as it passes through Canadian territory. Much of the route being unexplored, a table of distances and altitudes is not given.

## ROUTE FROM CORDOVA BAY TO EAGLE, BY WAY OF COPPER RIVER VALLEY.[a]

Cordova Bay is an eastern arm of Prince William Sound and lies about 30 miles west of Copper River. (Pl. II.) A proposed railway route is to follow the coastal margin of the mountains to Copper River and thence along that river. A corollary to this plan is to construct a branch line about 35 miles in length to the coal fields of Bering River (Controller Bay). (See map, Pl. XII, and p. 76.) The line up the Copper will require two bridges to avoid the glaciers which discharge into the water, but otherwise there appear to be no difficult engineering problems. As the route follows the river valley, the grade is easy.

One of the purposes of this railway is to develop the copper district, and it is therefore proposed to extend a branch line up Chitina River, which, with its feeders, will aggregate about 100 miles.

The extension of this road to Eagle would be carried through Mentasta Pass, which is a broad depression, with an altitude of about 2,900 feet. The cost of construction along the Copper Valley above the Chitina will be increased, because of the necessity of bridging the many tributary streams which flow in deep broad valleys. (Pls. V, VI, *B*.) A branch line could be constructed to tap the copper district, at the head of White and Tanana rivers, and another branch could be built down the Tanana to Fairbanks along the route already described. The following table gives the approximate distances and altitudes along this route:

*Elevations and distances, railway route from Cordova Bay to Eagle, by way of Copper River delta.*

| Point. | Elevation. | Distance between points. | Distance from Orca. |
|---|---|---|---|
| | *Feet.* | *Miles.* | *Miles.* |
| Cordova Bay (Orca) | 0 | 0 | 0 |
| Copper River | 50 | 30 | 30 |
| Tasnuna River | 200 | 45 | 75 |
| Taral | 500 | 50 | 125 |
| Copper Center | 1,005 | 56 | 181 |
| Chistochina | 1,810 | 58 | 239 |
| Mentasta Pass | 2,900 | 45 | 284 |
| Tanana crossing | 1,650 | 46 | 330 |
| Eagle | 800 | 160 | 491 |

Cordova Bay, an excellent harbor, is about 1,350 statute miles (1,200 nautical miles) from Seattle by sea. The adjacent region affords some good timber and water power.

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[a] This route is described in the following reports: Schrader, F. C., and Spencer, A. C., The Geology, and Mineral Resources of the Copper River District, Alaska, U. S. Geol. Survey, 1901. Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 331–391. Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell region, Alaska: Prof. Paper U. S. Geol. Survey No. 15, 1903. Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905. Prindle, L. M., The gold placers of the Fortymile, Birch Creek, and Fairbanks regions: Bull. U. S. Geol. Survey No. 251, 1905.

There are some promising copper deposits on Prince William Sound (see pp. 78–85), and the construction of a railway to the coal fields (pp. 76–77) might develop a local smelting industry. The railway would also tap two small producing placer districts, the Nizina and the Chistochina (see p. 7). The Yukon-Tanana placer districts reached by various extensions have already been referred to. The Copper River basin contains much good grazing and some agricultural land, and has sufficient timber for local use.

An alternate route for this line is from Copper Center (Pl. VII, *A*) through the pass at the head of the Delta (3,500 feet) and down the Delta, whose valley is, however, rather narrow, to Fairbanks. (Pl. VII, *A* and *B*.) The facts in regard to this route are indicated in the accompanying table.

*Elevations and distances, railway route from Copper Center to Fairbanks by way of Delta River.*

| Point. | Elevation. | Distance between points. | Distance from Copper Center. |
|---|---|---|---|
| | *Feet.* | *Miles.* | *Miles.* |
| Copper Center | 1,005 | 0 | 0 |
| Gulkana Divide | 3,500 | 100 | 100 |
| Delta River (mouth) | 690 | 50 | 150 |
| Fairbanks | 490 | 80 | 230 |

The advantage of building to Fairbanks instead of to Eagle is that the former is more centrally located for the placer districts and lies on navigable waters giving steamboat connection with other points. Moreover, at present it is making the largest output. A railway to Eagle would, however, undoubtedly become a competitor with the White Pass and Yukon Railway for the Klondike traffic, which is considerable.

## VALDEZ INLET-MARSHALL PASS-EAGLE ROUTE.

Surveys have been made for a railway to connect Valdez Inlet with Eagle by crossing Marshall Pass, descending Tasnuna River (see Pl. VIII) to Copper River, and then following that stream. After reaching Copper River the route is identical with that from Cordova Bay. Marshall Pass, 1,900 feet high and about 30 miles from tidewater, is reached by following the valley of Lowe River. Some of the details are presented in the following table, in which distances and altitudes are only approximate:

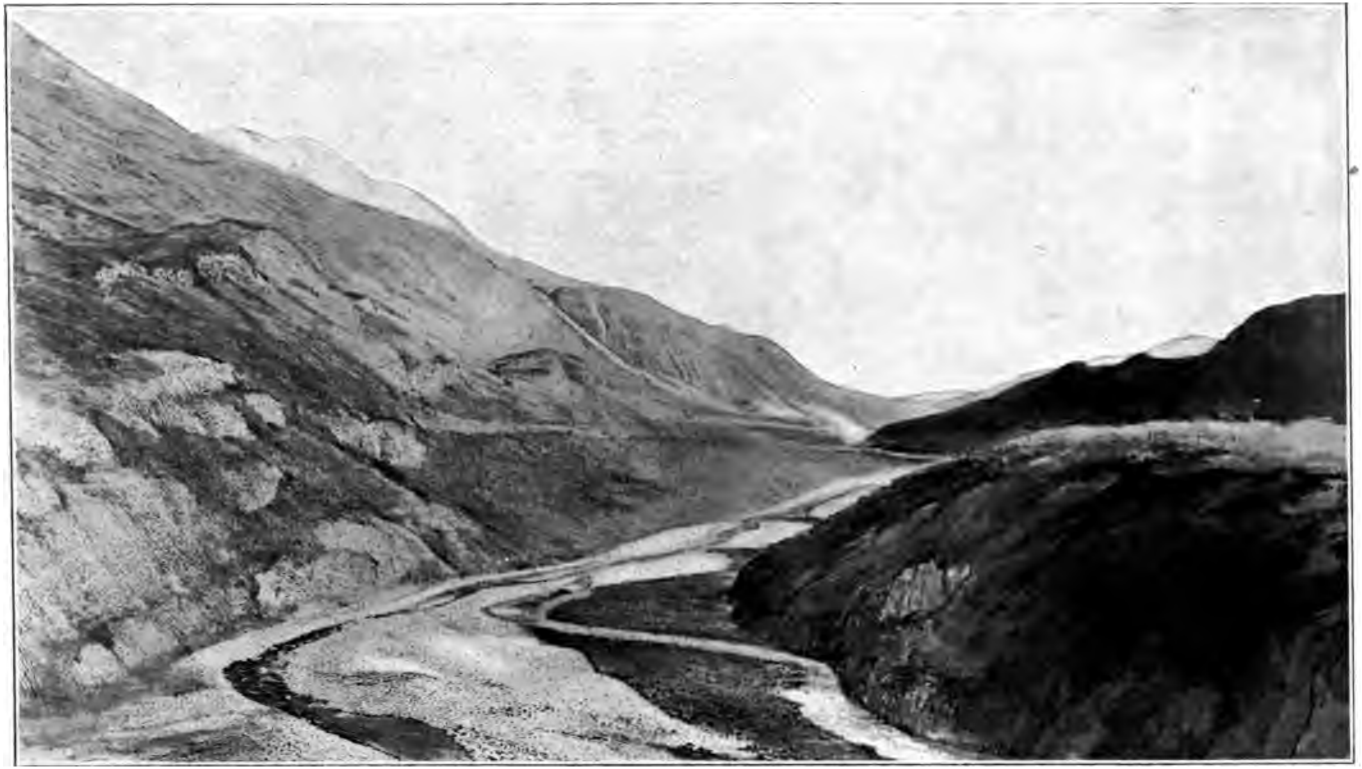
*Elevations and distances, railway route from Valdez to Eagle by way of Marshall Pass.*

| Point. | Elevation. | Distance between points. | Distance from Valdez. |
|---|---|---|---|
| | *Feet.* | *Miles.* | *Miles.* |
| Valdez | 0 | 0 | 0 |
| Marshall Pass | 1,900 | 30 | 30 |
| Tasnuna River | 200 | 31 | 61 |
| Taral | 500 | 50 | 111 |
| Copper Center | 1,005 | 56 | 167 |
| Chistochina | 1,810 | 58 | 225 |
| Mentasta Pass | 2,900 | 45 | 270 |
| Tanana crossing | 1,650 | 46 | 316 |
| Eagle | 800 | 161 | 476 |

The various branches and alternate routes are identical with those already described. To reach the copper deposits on the Chitina appears to be the first purpose of this proposed railway. It has been suggested that the line might be extended from the head of the Chitina to White River, but it would then have to traverse Skolai Pass, which is

*A*. DIVIDE BETWEEN DELTA AND COPPER RIVERS; RAILWAY ROUTE, COPPER CENTER TO FAIRBANKS.

*B*. UPPER VALLEY OF DELTA RIVER; RAILWAY ROUTE, COPPER CENTER TO FAIRBANKS.



TASNUNA RIVER VALLEY, RAILWAY ROUTE, VALDEZ INLET TO EAGLE BY WAY OF MARSHALL PASS.

glacier covered and has an altitude of probably 5,000 feet. The resources of this district have already been referred to.

Valdez Inlet, a western arm of Prince William Sound, affords a good coastal terminal about 1,400 statute miles (1,250 nautical miles) distant from Puget Sound. The valleys of the coastward-flowing streams are well timbered and there is some excellent water power.

There are not data enough at hand to discuss the relative merits of the Valdez Inlet and Cordova Bay routes. Each has its advocates, between which there is great rivalry. The distance to Eagle from Valdez is about 20 miles less than from Cordova Bay, but on the other hand the former route involves the crossing of Marshall Pass 30 miles from the coast, while the latter follows a water grade. The Cordova Bay route taps the Bering coal field, but is at a disadvantage in comparison with the other route in that it has to build two expensive bridges across the Copper.

In this connection mention should be made of an alternate plan (see map, Pl. XII) for tapping the coal field (see pp. 65–77), which involves the utilization of the shelter afforded by the Fox Islands, together with a breakwater to form a harbor near the coal field. It has been proposed to build a railway inland up Copper River from this terminal. Such a road would follow the same route as that already described from Cordova Bay. The success of the plan is dependent on the possibility of constructing a harbor at a cost not prohibitive.

## RESURRECTION BAY-SUSHITNA VALLEY-FAIRBANKS ROUTE.[a]

The Alaska Central Railway is now building from Seward, on Resurrection Bay, to the head of Knik Arm, and it is proposed to continue the line inland along the Sushitna Valley (Pl. IX, *A* and *B*) and through the Alaska Range to the Tanana at Fairbanks. In December, 1905, about 47 miles of track are said to have been laid and considerable grading done beyond.

This line leaves the Pacific seaboard at Resurrection Bay, and after crossing a pass less than 400 feet in height descends to tide water again at the head of Turnagain Arm. After swinging around the head of the arm it turns northward and crosses Matanuska River near its mouth. A branch is to be built up the Matanuska (Pl. XI, *A*) to the coal field, and it has been proposed to extend this into the Copper River basin.

The main line will probably follow the Sushitna (Pl. IX, *B*) and its western fork (Pl. X), the Chulitna, to Broad Pass, only about 2,000 feet in height and about 165 miles from tide water. Beyond the pass Cantwell River will be followed to the Tanana, along which the line can be continued to Fairbanks. Some further details in regard to this route are presented in the following table, in which the distances and altitudes are only approximate:

*Elevations and distances, railway route from Resurrection Bay to Fairbanks by way of Sushitna River.*

| Point. | Elevation. | Distance between points. | Distance from Seward. |
|---|---|---|---|
| | *Feet.* | *Miles.* | *Miles.* |
| Resurrection Bay (Seward) | 0 | 0 | 0 |
| Kenai Lake | 330 | 20 | 20 |
| Turnagain Arm | 0 | 50 | 70 |
| Mouth of Matanuska River | 0 | 75 | 145 |
| Talkeet River | 450 | 90 | 235 |
| Broad Pass | 2,000 | 105 | 340 |
| Tanana at mouth of Cantwell River | 450 | 110 | 450 |
| Fairbanks | 490 | 50 | 500 |

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[a] This route is described in the following reports: Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 1–29. Eldridge, G. H., A reconnaissance into the Sushitna basin, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 265–340. Brooks, A. H., A reconnaissance in the White and Tanana River basins, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 2, 1899, pp. 425–496. Moffit, F. H., The gold placers on Turnagain Arm: Bull. U. S. Geol. Survey No. 259, 1905, pp. 88–99. Moffit, F. H., and Stone, R. W., The mineral resources of the Kenai Peninsula: Bull. U. S. Geol. Survey No. 277 (in press).

Resurrection Bay, on the east side of the Kenai Peninsula, is an excellent harbor and ample wharves have already been constructed. The town of Seward is in a good location near the west end of the bay, about 1,400 statute miles (1,250 nautical miles) distant from Puget Sound. This part of the Kenai Peninsula is well timbered and the valley floors include some arable land. Beyond the first divide the railway skirts the eastern margin of the Sunrise placer district. About 100 miles inland the main line approaches within 30 or 40 miles of the Matanuska coal field (see pp. 88–100), the immediate objective point of the railway. An extension of the coal-field branch could be carried to Copper River by crossing a divide about 100 miles from tide water and about 2,500 feet high. (Pl. IX, *A*.) This proposed branch would tap the area and resources mentioned in connection with the proposed Copper River railways.

A discovery of placer gold is reported on the western side of the Sushitna basin, and if it proves of value will give additional business to this railway. The route will also traverse a small coal field lying in the headwater region of Cantwell River. This coal, though of a lignitic character, might find a market at Fairbanks, from which it is only 60 miles distant. (See pp. 112–113.) One important feature of this route is that it traverses the Sushitna basin, which has an area of about 8,000 square miles and is generally conceded to be the best agricultural land in Alaska. This province will no doubt be the first to attract settlers and a railway will therefore be an important factor in assuring a permanent population to the Territory. In common with the other routes it traverses the Tanana Valley, which contains much grazing and arable land. It will afford communication with the Fairbanks placer district and by branch lines can be made to afford an outlet to the Birch Creek and Rampart districts. Moreover, at the Tanana it reaches navigable water and will have steamboat connection with much of the Yukon River system.

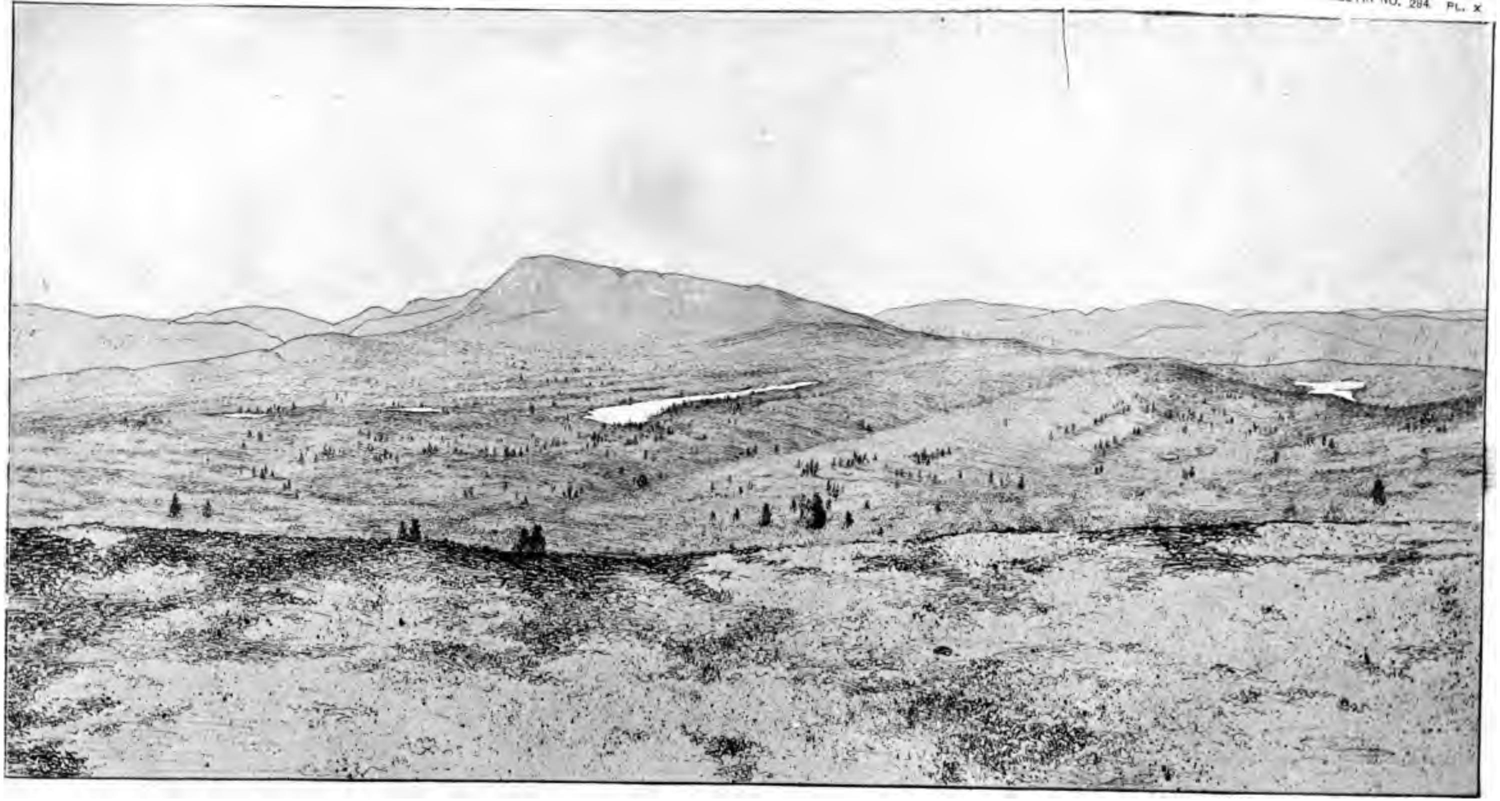
The Sushitna route appears to have the advantage over a number of others in the matter of grades, for it traverses the mountains by a pass only 2,000 feet in altitude and that is about 200 miles inland. It also passes through a region better timbered and having greater agricultural possibilities than some of the other routes. It can, however, be made to reach the copper districts only by a branch whose mileage would be greater than a direct line to this field from Valdez or Orca. A Resurrection Bay-Fairbanks railway can therefore not be considered a direct competitor with those projected from Prince William Sound. In the opinon of the writer the opening up of untouched mineral wealth should result in business enough for a railway from Resurrection Bay, as well as one from Prince William Sound.

## ROUTES FROM COOK INLET TO YUKON RIVER.

This paper concerns itself primarily with railways whose purpose is to open up inland Alaska, but it will be well to consider briefly the routes from Cook Inlet to Yukon River. (See map, Pl. II.) It has been proposed to build a railway to Seward Peninsula from the western side of Cook Inlet. Though little is known of the region which would be traversed by such a railway, it is certain that there are no mountain ranges to cross. The distance to the lower Yukon is about 450 miles and to Nome about 300 miles farther. The lower end of Cook Inlet is free from ice throughout the year and there are several bays which could be used as coastal terminals. So far as known, the first divide to be traversed within 20 miles of Cook Inlet is said to be only 800 feet above the sea. A second divide, about 100 miles beyond, between Bristol Bay and Kuskokwim waters, is probably less than 2,000 feet high. Little is known of the resources of that part of the Kuskokwim basin which would be traversed by this route. There is, however, a fair grade of bituminous coal on the lower Yukon, and Seward Peninsula is one of the great centers for placer mining in the Territory. It must be born in mind, however, that during the open season water transportation would come in direct competition with any railway built to Nome.

*A*. UPPER MATANUSKA VALLEY; RAILWAY ROUTE UP MATANUSKA VALLEY TO COPPER RIVER.

*B* LOWER SUSHITNA VALLEY; RAILWAY ROUTE, RESURRECTION BAY TO FAIRBANKS.



UPPER SUSHITNA VALLEY; RAILWAY ROUTE, RESURRECTION BAY TO FAIRBANKS.

## SUMMARY.

In the foregoing pages an attempt has been made to present a concise and unprejudiced statement of the known facts bearing on railway routes into Alaska from the Pacific. The subject is large and can not be adequately discussed in the few pages devoted to it. Moreover, the data are very incomplete, but it is hoped that this outline may be of service to those who are interested.

In the matter of climate there is little to choose between the various routes. Everywhere along the coast there is a heavy winter snowfall which will necessitate large expenditures to keep the tracks open. The harbors along the Pacific seaboard, except the upper part of Cook Inlet, are open to navigation throughout the year. Beyond the coastal mountains the climate changes to semiarid conditions, and the snowfall of 2 to 3 feet will not seriously interfere with traffic. The coastal zone is usually heavily forested and will furnish much of the timber needed for construction and ties. The attention of engineers who are unfamiliar with the conditions in inland Alaska should be called to the fact that in many places the ground remains frozen to bed rock throughout the year. When the coating of turf is removed, the gravel thaws out rapidly and this action continues, making it difficult to construct lasting foundations, except where built on bed rock. This is especially true of the hill slopes, but the alluvium of the valley floors is not frozen.

There are no data at hand of the tonnage of freight now being sent into central Alaska, and still less can it be foreshadowed what the increase of business will be with railway communication. Certain it is, however, that there are hundreds, if not thousands, of placers which could be developed if mining costs were reduced. There are at least two coal fields which are only awaiting railways to be extensively developed, while the copper deposits, too, appear to have great value.

# MARKETS FOR ALASKA COAL.

By G. C. MARTIN.

## INTRODUCTION.

The question of markets for Alaska coal is a vital one in connection with the present activity in the development of coal lands. Numerous requests for information concerning the facts bearing on this question have been received, but the data are incomplete and scattered. The following discussion is based on all facts which could be gathered from previous compilations and from new investigations. The problem has already been discussed by Brooks,[a] but as more complete information is now available and as it seems well to give these facts a place in the Survey publications, the present paper has been prepared.

## PRESENT CONSUMPTION OF FUEL.

### AMOUNT AND SOURCES.

The coal consumption of Alaska from June, 1904, to June, 1905, is estimated at 120,000 tons, derived from the following sources:

*Consumption of coal in Alaska, June, 1904, to June, 1905.*

| | Long tons. |
|---|---|
| Local supply | [b] 2,000 |
| Imported from United States | [c] 42,500 |
| Imported from foreign countries, chiefly British Columbia | [c] 75,500 |
| | 120,000 |

It is estimated that at least 137,000 tons additional are consumed by steamers plying between United States or foreign ports and Alaska. This fuel comes largely from the home ports of the steamers or chiefly from Puget Sound. The fuel of local coastwise and river boats is, however, included in the total of 120,000 tons. The total coal consumed in Alaska and on voyages thereto is at least 257,000 long tons.

This is not the entire amount of fuel used, for there is a large but unknown amount of wood burned and over 2,700,000 gallons of crude petroleum and 700,000 gallons of naphtha were shipped to Alaska during 1905.

### DISPOSAL.

This coal is consumed approximately as follows:

*Distribution of coal consumed in Alaska, June, 1904, to June, 1905.*

| Towns and mines: | Long tons. |
|---|---|
| Southeastern Alaska | [d] 55,000 |
| Prince William Sound, Cook Inlet, and Alaska Peninsula | [d] 5,000 |
| Seward Peninsula | [d] 35,000 |

---

[a] Brooks, A. H., The outlook for coal mining in Alaska: Trans. Am. Inst. Min. Eng., vol. 36, 1905, pp. 683-702.

[b] Estimated.

[c] From table on p. 19.

[d] Rough estimate. The individual items may not be exact, but the total of these items (120,000 tons), as given in the preceding table, is fairly accurate.

| | Long tons. |
|---|---|
| Canneries and cannery boats | |
| Southeastern Alaska | [a] 5,000 |
| Cook Inlet, Prince William Sound, Kodiak, and southern coast of Alaska Peninsula | [a] 5,000 |
| Bristol Bay | [a] 5,000 |
| Steamers: | |
| Local coastwise and river steamers (excluding cannery boats) | [a] 10,000 |
| Puget Sound to southeastern Alaska | [b] 45,000 |
| Puget Sound to Prince William Sound and Cook Inlet | [b] 23,000 |
| Puget Sound to Nome | [b] 32,000 |
| San Francisco to Alaska | [c] 7,000 |
| British Columbia to southeastern Alaska | [c] 25,000 |
| Foreign ports to Nome | [c] 5,000 |
| | 257,000 |

The bulk of the crude petroleum was used in Seward Peninsula and on the Yukon, while the larger part of the naphtha went to the same regions, the remainder being used on the Pacific coast. Almost all of the crude petroleum and naphtha were used for generating heat and power, the petroleum under boilers and the naphtha in engines.

## PROBABLE INCREASE IN CONSUMPTION.

The increase in shipments of coal to Alaska during the last three years is shown in the following table:[d]

*Shipments of coal to Alaska, July 1, 1902, to June 30, 1905.*

| | 12 months ending June 30, 1903. | | 12 months ending June 30, 1904. | | 12 months ending June 30, 1905. | |
|---|---|---|---|---|---|---|
| | Long tons. | Value.[a] | Long tons. | Value.[a] | Long tons. | Value.[a] |
| Domestic anthracite | 20 | $276 | | | 5 | $85 |
| Domestic bituminous | 56,120 | 255,841 | 41,704 | $193,740 | 42,245 | 187,352 |
| Domestic coke | 65 | 288 | 392 | 2,251 | 478 | 4,281 |
| Canadian bituminous | 54,072 | 216,089 | 63,652 | 261,987 | [b] 69,500 | [b] 286,000 |
| Australian bituminous | | | 1,609 | 4,303 | | |
| Foreign bituminous, shipped via United States | 40 | 350 | 3,324 | 23,904 | 5,550 | 29,673 |
| | 110,317 | 472,844 | 110,681 | 486,185 | 117,778 | 507,391 |

[a] At port of shipment. [b] Estimated.

The increase in consumption so far as it is influenced by existing factors should continue for some years in about the same ratio as shown in the foregoing tables. A further increase is to be expected with the initiation of new enterprises, such as the building of railroads and smelters. These factors of increase will act directly in the fuel actually consumed by such enterprises, and indirectly in the stimulus to trade and the increase in population which will result. Neither of these direct factors will be large at first. A few small mines along the railroads will supply all the fuel which they will consume, while all the copper ore produced in Alaska during the last year can be smelted with less than 5,000 tons of coke. These items will, however, probably both increase very rapidly and must be considered very important factors in the development of local industries. Mines situated on the coast or having tidewater connections will probably be able to supply a large part of the bunker coal consumed on both local steamers and those from the United States and foreign ports. This now amounts to 147,000 tons, divided as is shown in the table at top of this page.

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[a] Rough estimate. The individual items may not be exact, but the total of these items (120,000 tons), as given in the preceding table, is fairly accurate.
[b] From data furnished chiefly by the steamship companies.
[c] Computed from tonnage and horsepower of boats.
[d] Commerce of the noncontiguous Territory of the United States, Bureau of Statistics, 1903, 1904, 1905.

Mines shipping first-class coal from ports on Controller Bay, Prince William Sound, or Cook Inlet should be able to secure immediately half or possibly all of the patronage of steamers running to Prince William Sound and Cook Inlet, provided the prices are right. A large proportion of the patronage of the other Alaska steamers can probably be secured by shipping the coal either to the Alaska termini of these lines or to Puget Sound or San Francisco. The aggregate tonnage of Alaska steamers, according to reports of the Bureau of Statistics, is now increasing at the rate of 6 per cent per annum. This rate of increase will probably be greater in the future.

## LOCAL SOURCES OF SUPPLY.

Coal is widely distributed in Alaska, but because of the peculiar economic conditions in regard to markets and cost of development and transportation it is only at favored localities that profitable coal mining may be expected in the near future. The conditions which determine these localities are local demand, quality of the coal, cost of mining, and cost of transportation. The regions which seem likely to fill these conditions in the near future are the Matanuska River and Bering River fields, near the Pacific coast, and to a less degree the Seward Peninsula, Yukon River, and possibly the southwestern Alaska regions. Coal mining may develop on a small scale in other districts, especially should there be local markets near the coal mines.

### ANTHRACITE AND BITUMINOUS.

#### BERING RIVER.

The Bering River coal field[a] covers an area of about 70 square miles, including 25 square miles of anthracite and 45 square miles of semianthracite (or semibituminous) coking coal. The seams are numerous and very large; several exceed 20 feet in thickness. The average quality of the Bering River coal is excellent, several of the seams being remarkably low in both ash and sulphur.

Bering River coal is not now available for sale in any market, but there are prospects that transportation will soon be provided to tide water on Controller Bay, Katalla Bay, or Prince William Sound. (See map, Pl. XII.)

#### MATANUSKA RIVER.

There is an area of at least 70 and possibly several hundred square miles of coal in the Matanuska Valley. This includes anthracite, semibituminous coking coal, and a lower grade of bituminous coal. The seams are of good thickness and well situated for mining. Transportation to Resurrection Bay on the Pacific coast and into the interior will soon be provided by the Alaska Central Railway now under construction. This field is described in more detail on pages 88-100.

#### OTHER BITUMINOUS FIELDS.

There is considerable high-grade semibituminous coal at Cape Lisburne[b] which is rather inaccessible, but which may sometime find a market. Part of the coal on Yukon River[c] is a fair grade of bituminous and should with proper management find a limited local market. Bituminous coal of fair quality is known from several places on the Alaska Peninsula.[d]

### LIGNITE.

Lignite occurs in numerous regions in Alaska, having wide distribution and great areal extent. Most of the information regarding it has already been summarized[e] and need not be repeated here.

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[a] For further description of this field see the following reports: Bull. U. S. Geol. Survey No. 225, 1904, pp. 365-382; Bull. U. S. Geol. Survey No. 250, 1905, pp. 11-36; Bull. U. S. Geol. Survey No. 259, 1905, pp. 140-150, and this bulletin, pp. 65-77.

[b] Collier, A. J., Bull. U. S. Geol. Survey No. 259, 1905, pp. 172-185; No. 278 (in press).

[c] Collier, A. J., Bull. U. S. Geol. Survey No. 218, 1903.

[d] Stone, R. W., Bull. U. S. Geol. Survey No. 259, 1905, pp. 151-172.

[e] Dall, W. H., Report on the coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 769-908. Brooks, A. H., Coal resources of Alaska: Twenty-second Ann. Rept. U. S Geol. Survey, pt. 3, 1902, pp. 517-571. Collier, A. J., Coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903. Stone, R. W., Coal of southwestern Alaska: Bull. U. S. Geol. Survey No. 259, 1905, pp. 151-172. Moffit, F. H, Bull. U. S. Geol. Survey No. 247, 1905, p. 67.

## COMPETITION WITH PETROLEUM.

The competition between coal and petroleum very seriously affects the possibility of developing an important coal-mining industry in Alaska. The use of petroleum has already stopped the mining of coal on the Yukon for the river steamers and has driven out part of the imported coal used both there and in other parts of Alaska. It has also, to a large extent, forced the Washington, Oregon, and British Columbia coals from the San Francisco market, thus spoiling what might otherwise be a very important market for Alaska coal.

### USE OF PETROLEUM IN ALASKA.

The importation of petroleum and its fuel products into Alaska is shown in the following table:

*Shipments of petroleum to Alaska.*[a]

| | Crude petroleum. | | | Naphthas. | |
|---|---|---|---|---|---|
| | Gallons. | Barrels. | Value. | Gallons. | Value. |
| Six months ending— | | | | | |
| December, 1902 | 21,000 | 500 | $390 | 60,358 | $12,186 |
| June, 1903 | 840,000 | 20,000 | 28,000 | 210,147 | 33,831 |
| December, 1903 | 1,008,000 | 24,000 | 36,000 | 84,776 | 18,054 |
| June, 1904 | 1,008,400 | 24,010 | 35,828 | 231,658 | 43,814 |
| December, 1904 | 1,008,030 | 24,001 | 33,603 | 106,623 | 23,904 |
| June, 1905 | 1,780,326 | 42,389 | 59,204 | 499,196 | 75,187 |
| December, 1905 | 935,060 | 22,263 | 31,864 | 214,300 | 34,734 |

[a] Monthly Summary of Commerce and Finance, Bureau of Statistics, 1902–1905.

### EFFECT OF CALIFORNIA PETROLEUM ON PACIFIC COAST COAL TRADE.

It is believed by many that the coal industry on the Pacific coast will not be able to survive this competition, but that California petroleum, because of its lower cost, will ultimately displace coal in all uses to which petroleum is applicable. The statistics contained in the following tables will shed some light on this subject:

*Relation of production of petroleum to output and price of coal on the Pacific coast.*

| Year. | Production of petroleum in California (barrels).[a] | Production of coal on the Pacific coast (short tons). | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | California.[b] | | Oregon.[c] | | Washington.[d] | | Vancouver Island.[e] | Total Pacific coast production.[f] |
| | | Amount. | Price per ton. | Amount. | Price per ton. | Amount. | Price per ton. | Amount. | |
| 1895 | 1,208,482 | 75,453 | $2.33 | 73,685 | $3.36 | 1,191,410 | $2.16 | 1,058,645 | 2,398,595 |
| 1896 | 1,252,777 | 78,544 | 2.12 | 101,721 | 2.90 | 1,195,504 | 2.00 | 1,003,769 | 2,379,538 |
| 1897 | 1,903,411 | 85,992 | 2.34 | 107,289 | 2.72 | 1,434,112 | 1.94 | 1,019,390 | 2,646,693 |
| 1898 | 2,257,207 | 144,288 | 2.43 | 58,184 | 3.65 | 1,884,517 | 1.78 | 1,263,154 | 3,350,142 |
| 1899 | 2,642,095 | 160,715 | 2.67 | 86,888 | 3.00 | 2,029,881 | 1.78 | 1,319,101 | 3,596,577 |
| 1900 | 4,324,484 | 171,708 | 3.05 | 58,864 | 3.74 | 2,474,093 | 1.90 | 1,365,580 | 4,070,245 |
| 1901 | 8,786,330 | 151,079 | 2.60 | 69,011 | 2.51 | 2,578,217 | 1.62 | 1,413,153 | 4,211,460 |
| 1902 | 13,984,268 | 84,984 | 2.99 | 65,648 | 2.44 | 2,681,214 | 1.72 | 1,324,760 | 4,156,606 |
| 1903 | 24,382,472 | 104,673 | 2.82 | 91,144 | 2.42 | 3,193,273 | 1.69 | 927,200 | 4,316,290 |
| 1904 | 29,649,434 | 78,888 | 4.76 | 111,540 | 2.18 | 3,137,681 | 1.63 | 1,054,864 | 4,382,973 |

[a] Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905, p. 722.
[b] Idem, pp. 458–459.
[c] Idem, p. 530.
[d] Idem, p. 564.
[e] Ann. Repts. Minister of Mines, British Columbia.
[f] Computed from items in this table.

NOTE.—The price per ton as given in the above table represents "spot value" at the mines.

*Variation in amount of coal produced and used on the Pacific coast (short tons).*

| Year. | Total Pacific coast production.[a] | Shipments of coal to the Pacific coast.[b] | Coal consumed on Pacific coast.[a] | Coal consumed in California.[b] | Coal consumed on Pacific coast outside California.[a] |
|---|---|---|---|---|---|
| 1895 | 2,398,595 | 510,120 | 2,908,715 | 1,653,520 | 1,255,195 |
| 1896 | 2,379,538 | 458,727 | 2,838,267 | 1,505,660 | 1,332,607 |
| 1897 | 2,646,693 | 421,638 | 3,068,331 | 1,601,540 | 1,466,791 |
| 1898 | 3,350,142 | 346,222 | 3,696,364 | 1,802,373 | 1,893,991 |
| 1899 | 3,596,577 | 299,947 | 3,896,524 | 1,740,027 | 2,156,497 |
| 1900 | 4,070,245 | 292,654 | 4,362,899 | 1,889,128 | 2,473,771 |
| 1901 | 4,211,460 | 306,746 | 4,518,206 | 1,834,785 | 2,683,421 |
| 1902 | 4,156,606 | 368,062 | 4,524,668 | 1,445,598 | 3,079,070 |
| 1903 | 4,316,290 | 456,742 | 4,773,032 | 1,215,554 | 3,557,478 |
| 1904 | 4,382,973 | 298,039 | 4,681,012 | 1,051,072 | 3,629,940 |

[a] Computed from items in this table.

[b] The production of coal in 1904 (separate publication of Mineral Resources U. S.), U. S. Geol. Survey, 1905, p. 102.

During the ten years (1895 to 1904) covered by these tables there has been an extraordinary increase in the output of California petroleum. The production in 1904 (29,649,434 barrels) is 24½ times the amount produced in 1895 (1,208,482 barrels). As this was nearly all fuel oil, it might be expected that it would displace a large amount of coal and that we would find throughout the same period a corresponding decrease in coal mining and coal trade not only in Calfornia, but in the other regions which supply California with coal. The statistics, however, show that the production of coal in California increased from 1895 to 1900 and has fluctuated, but on the whole fallen off since that time. The production in Oregon has shown an irregular, but quite general, increase during this ten-year period. The Washington mines have increased their product to almost triple. Vancouver Island mines had the same output at the end of the period as at its beginning, but showed a rise and subsequent fall during the interval. Shipments from Atlantic and oriental ports have decreased somewhat irregularly, but very decidedly, during these ten years. The amount of coal consumed in California has varied irregularly, but has on the whole shown a decided decrease. This, however, applies to California alone. The amount of coal consumed on the Pacific coast as a whole (from California north) has increased from 2,908,715 tons in 1895 to 4,681,012 tons in 1904. The increase on the Pacific coast outside of California is even more striking, the amount having risen from 1,255,195 tons in 1895 to 3,629,940 tons in 1904.

The price of coal mined in California has increased during the period under discussion. Oregon and Washington coal has decreased in value. No figures are at hand regarding the prices of Vancouver Island or other imported coals.

The general effect of the increase in petroleum has been to demoralize the San Francisco coal market. The gradual increase in oil output from 1895 to 1900 was accompanied by a very prosperous condition of the coal trade, not only in California, but throughout the country. After this the output of oil became so great as to preclude all possibility of competition by coal in the oil territory except for special uses to which oil can not be applied—that is, coal was forced to seek markets of its own, which include, in addition to the special one mentioned above, those districts in which the relative freight charges on coal and oil make competition possible. In the former the price of coal rose and the demand increased. This result may be attributed to the very factor which in other respects demoralized coal trade. The increase in petroleum output, furnishing a cheap and abundant fuel, stimulated general industrial conditions, and thus increased the demand for coal in its special markets.

The cutting down of shipments from the other Pacific coast fields to San Francisco has resulted in a reduction in prices, caused by the attempt to compete with the cheaper petroleum and by the lively competition of the coal mines among themselves in attempting to develop and control new markets nearer home. They have been successful in their home markets, as may be seen by the great increase (289 per cent) in consumption of coal on the northern Pacific coast during the last ten years. This means a large increase in manufacturing and other business interests and indicates that there is a substantial permanent increase in the demand for coal, which, barring overproduction or an unlooked-for invasion of petroleum, will ultimately lead to an upward tendency in prices.

## CAPABILITY OF COAL TO COMPETE WITH PETROLEUM.

The following factors determine the possibility and result of competition between coal and oil:

1. Relative adaptability of coal and oil to the special use under consideration.
2. Relative efficiency of oil and coal.
3. Relative prices as determined by cost of production and freight.
4. Supply available.

### RELATIVE ADAPTABILITY.

The factor of relative adaptability determines the special markets for coal or for oil in which the other can not compete at any price. Much of the Alaska coal is of such quality that it is especially suitable for use as a domestic fuel. As such it should find a widespread market along the Pacific coast, selling at a good price in San Francisco and the California oil fields. Competition with oil will be slight, at least until improvements are made in the methods of burning oil. Competition with other coals will be considered in another place.

There is much high-grade coking coal in Alaska, and coke will not come into competition with petroleum, but will sell independent of the presence and cost of oil, the price being determined solely by competition with other cokes. The present and prospective increase in steel and smelter industries will create a strong demand for coke.

The Alaska mines will also furnish a high-grade blacksmith's coal. Petroleum will not compete for this purpose. In fact, the oil fields themselves will constitute one of the most attractive markets, and any extension of the oil fields will create new demand for blacksmith's coal. The present supply of such coal on the Pacific coast is largely brought from the East at great cost.

It does not seem practicable at present to adapt petroleum to general naval use. Petroleum will consequently not compete with Alaska coal in this market. Much of the Alaska coal is well adapted for use on war ships or wherever high-grade smokeless steaming coal is required. The only effect which petroleum has at present in this market is to render other coal available for competition, and thus indirectly to reduce the selling price. If naval architects succeed in solving the structural and storage problems which at present keep petroleum from being used in this way conditions will be changed, for petroleum has many advantages over coal for this use.

### RELATIVE EFFICIENCY.

The factor of relative efficiency is determined primarily by the quality of the coal, the fuel value of petroleum being more nearly constant.

The United States Naval "Liquid Fuel" Board has obtained the following results from tests with the Hohenstein marine water-tube boiler:

*Equivalent evaporation from and at 212° F. per pound of oil.*[a]

| | Pounds. |
|---|---|
| Beaumont petroleum (average of 47 tests) | 12.51 |
| California petroleum (average of 20 tests) | 11.57 |
| Mixture (dregs) of Beaumont and California petroleum (average of 2 tests) | 11.52 |

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[a] Rept. U. S. Naval "Liquid Fuel" Board, 1904, pp. 250-252

*Equivalent evaporation from and at 212° F. per pound of coal as fired.*[a]

| | Pounds. |
|---|---|
| Pocahontas coal, run of mine (average of tests 1 to 3) | 8.65 |
| Pocahontas coal, run of mine (average of tests 4 to 6) | 9.40 |
| New River coal, run of mine (average of tests 7 to 9) | 9.37 |
| Pocahontas coal, hand picked and screened (average of tests 10 to 17) | 9.30 |

The character of the coal used in these tests is shown in the following table, of which it is said:[b]

> From each can or bag of coal that was brought into the fireroom a specimen was taken and collected in a box, so that there could be forwarded for analysis a fair sample of the fuel used.
>
> The following table gives the result of analyses of samples of each lot of coal. The analyses were made by the chemist at the New York Navy-yard:

*Analyses of coal used in comparative fuel tests.*

| Coal. | Moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Fuel ratio. |
|---|---|---|---|---|---|---|
| Pocahontas coal, run of mine, used in tests 1 to 3 | 0.49 | 17.61 | 73.30 | 8.60 | 0.48 | 4.16 |
| Pocahontas coal, run of mine, used in tests 4 to 6 | .79 | 19.53 | 75.78 | 3.90 | .71 | 3.88 |
| New River coal, run of mine, used in tests 7 to 9 | .49 | 21.79 | 72.99 | 4.73 | .46 | 3.35 |
| Pocahontas coal, hand picked and screened, used in tests 10 to 17 | .73 | 19.62 | 76.81 | 2.84 | .73 | 3.91 |

| Coal. | C. | H. | O. | N. | S. | Ash. | B. T. U.[a] |
|---|---|---|---|---|---|---|---|
| Pocahontas coal, run of mine, used in tests 1 to 3 | 82.26 | 3.89 | 4.12 | 0.64 | 0.49 | 8.60 | 14,067 |
| Pocahontas coal, run of mine, used in tests 4 to 6 | 84.96 | 4.07 | 5.46 | .90 | .71 | 3.90 | 14,534 |
| New River coal, run of mine, used in tests 7 to 9 | 83.60 | 4.85 | 4.87 | 1.41 | .46 | 4.81 | 14,841 |
| Pocahontas coal, hand picked and screened, used in tests 10 to 17 | 85.94 | 4.45 | 4.50 | 1.14 | .82 | 3.15 | 14,992 |

[a] The British thermal unit (B. T. U.) is the amount of heat required to raise the temperature of 1 pound of water 1° F. at or near 39.1° F. It is equal to 0.55 calorie.

The following conclusions are stated in the report:[c]

> The relative evaporative efficiency of oil and coal as a fuel, as determined by this extended series of comparative experiments, is practically in the proportion of 15 to 10. The actual superiority of oil will be considerably greater, for in the coal experiments unusual skill was exercised in the management of the fires. Lump coal of superior quality was used; and as the tests with coal were of comparatively short duration, the resulting loss from cleaning fires was much less than would occur in actual service. The oil experiments, however, were carried on under conditions that more closely approximated those that could be secured on board the seagoing vessel. The actual evaporative efficiency of a pound of oil as compared with a pound of coal will therefore be in the ratio of 17 to 10, and these figures can be regarded as substantially correct.

* * * * * * *

> In noting the comparative economic efficiency, for naval purposes, of oil and coal, there must also be taken into consideration the fact that a ton of oil can be stowed in somewhat less space than a ton of bituminous coal. Then, again, it must be considered that in the carrying of the oil the compartments can be more completely filled. The relative efficiency of oil and good steaming coal from the naval standpoint of fuel supply in war ships may thus be regarded as in the ratio of 18 to 10.

It was found by comparative tests of coal and oil on the steamship *Alameda* between San Francisco and Honolulu that the efficiency of oil fuel and a mixture of British Columbia and Australia coal was in the ratio of 1.42 to 1, or 1 ton of coal equaled 4.10 barrels of oil.

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[a] Rept. U. S. Naval "Liquid Fuel" Board, 1904, p. 52.
[b] Op. cit., p. 10.
[c] Op. cit., pp. 417, 418.

The following quotations will show the relative values of various coals in comparison with petroleum:

> Tests have proved that 1 pound of California petroleum used on a passenger locomotive evaporated 10.96 pounds of water from and at 212° F., as compared with 7.14 pounds of water under like conditions evaporated by 1 pound of Comox bituminous coal, or 4 barrels of oil did the work of 1 ton of coal. This is rather below the results attained by other tests, which in many cases showed that from 3¼ to 3½ barrels of petroleum did the work of 1 ton of coal.[a]

*Number of barrels of petroleum equivalent to 1 ton of various coals and value of coals per ton, as compared with petroleum at $1 per barrel.*[a]

| One pound of combustible. | Pounds of water evaporated at 212° F. per pound of combustible. | Barrels of petroleum required to do the same amount of evaporation as 1 ton of coal. | Cost of coal per ton to equal petroleum at $1 per barrel. | Less 10 per cent owing to the greater economy in handling petroleum. |
|---|---|---|---|---|
| Petroleum 15° to 18° Baumé | 16.0 | | | |
| Cardiff lump, Wales | 10.0 | 4.0 | $4.00 | $3.60 |
| Cape Breton, Canada | 9.2 | 3.7 | 3.70 | 3.33 |
| Nanaimo, British Columbia | 7.3 | 2.9 | 2.90 | 2.61 |
| Cooperative, British Columbia | 8.9 | 3.6 | 3.60 | 3.24 |
| Greta, Washington | 7.6 | 3.0 | 3.00 | 2.70 |
| Carbon Hill, Washington | 7.6 | 3.0 | 3.00 | 2.70 |

[a] Oliphant, F. H., The production of petroleum in 1903: Mineral Resources U. S. for 1903, U. S. Geol. Survey, 1904, p. 685.

The following estimates have been gathered from various sources:

*Equivalent in petroleum of 1 ton of various coals.*

| | Barrels petroleum. |
|---|---|
| Pocahontas coal | 4.5 |
| Georges Creek coal | 4.3 |
| Pittsburg coal | 4.3 |
| Nanaimo coal | 3.2 |
| Carbon Hill coal | 2.7 |

There is some variation in the values given. This may be ascribed in part to differences in quality of the coal in different parts of the same field, in part to differences in the efficiency of the boilers, in part to differences in fuel value of various petroleums, and in part to errors.

There is, however, no doubt that a large part of the Bering River and Matanuska coal is of such high grade that a ton of it will equal at least 4 barrels and probably 4.5 barrels of California oil. The lower grade Alaska bituminous coals should stand in the ratio of 1 ton of coal to 2.6 or 3.6 barrels of petroleum. One ton of the better Alaska lignites is probably equal to 2.5 or 3 barrels of petroleum. The poorer lignites should give a ratio of 1 ton to 2 or 2.5 barrels.

These figures are all based on the relative efficiency of coal and petroleum when used with a steam engine. The values representing the relative efficiency of these fuels when used with a gas engine,[b] or for direct heat (as in roasting or smelting, or in a stove), might be very different.

### RELATIVE PRICES.

It is impossible for the writer to make any definite estimate of the cost of producing and shipping Alaska coal. It would seem, however, that it should not be much in excess of the cost in many other western mining districts. It is reasonable to assume that with proper management it could be reduced below the present selling price on Vancouver Island.

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[a] Oliphant, F. H., The production of petroleum in 1901: Mineral Resources U. S. for 1901, U. S. Geol. Survey, 1902, p. 583.

[b] See Preliminary report on the operations of the coal-testing plant, etc.: Bull. U. S. Geol. Survey No. 261, 1905, pp. 16, 17, 85-120.

Freight rates from Bering River and Matanuska mines to tide water ought not to be excessive and rates from Alaska to Puget Sound or San Francisco should be very low.

The price of California crude petroleum at the wells ranged in 1904 from 17½ cents to $2 per barrel, depending both on local and temporary differences in supply and demand and on differences in quality. The average price was about 28 cents per barrel, as compared with 30 cents in 1903. The cost per barrel delivered at San Francisco was from $1.40 to $1.50 in 1904.

These prices in equivalents of Puget Sound coal are as follows:

Petroleum at $0.12½ per barrel=coal at $0.37½ per ton.
Petroleum at $0.28 per barrel=coal at $0.84 per ton.
Petroleum at $1.40 per barrel=coal at $4.20 per ton.
Petroleum at $1.50 per barrel=coal at $4.50 per ton.

These values should be about 25 to 33 per cent greater for the best Alaska coal. They show that it is impossible for any coal to compete with fuel oil in those districts where oil has the advantage of transportation rates. It is possible, however, that rates to San Francisco might be made such that coal and oil can compete. There ought to be lively competition north of San Francisco, if the cost of mining and shipping coal is reduced to a minimum.

### SUPPLY AVAILABLE.

It is not likely that enough of either petroleum or coal could be produced on the Pacific coast to supplant the other without soon proving inadequate to the demand, in which case there would be an advance in price and consequent reopening of competition.

The following conclusions[a] are of interest on this point:

> Careful consideration has been given the question as to the supply of crude petroleum in the United States available for fuel purposes. This matter has been specially investigated by Prof. Arthur L. Williston, of the Pratt Institute, Brooklyn, N. Y., who reports as follows:
>
> "The supply of oil which is available for fuel in the United States, therefore, is, first, the small percentage (probably not over 2 or 3 per cent) of the total production of the Pennsylvania and Ohio oil—the residuum from the process of refining; second, crude oil from the Ohio and Indiana fields wherever the price of coal makes the burning of oil at 95 cents or $1 per barrel (plus freight) profitable: third, those portions of the California oil which are not best suited for refining; fourth, practically the entire output of the Texas field."
>
> The demands for the better grades of oil for refining purposes will probably keep pace with its production, consequently we can never expect to see such grades of oil compete with coal to any large extent.
>
> On the other hand, the refining value of the Texas oil and much of the California oil is so low that its value will probably always be largely controlled by the demand for it for fuel purposes. It is inconceivable that a fuel which has so many distinct advantages, and which is not unlimited in its supply, should sell in all markets at a price which would make it cheaper to burn than coal. Any great demand for such a fuel would bring its price up at once.
>
> On the other hand, so long as there is an assured supply of Texas and California fuel oil, the price of such oil that has little intrinsic value for refining will probably remain low enough to enable it to compete successfully with coal in those regions where coal is scarce in quantity and poor in quality; and the area in which this condition exists is sufficiently wide to create a demand for the fuel oil that will soon equal the supply, unless further stores of oil are found as the demand for it increases.
>
> The fact should be remembered that in every region there is with each succeeding year a progressive proportionate increase in the percentage of the yield consumed for illuminating purposes

The petroleum output of California in 1904, which was more than one-fourth (25.33 per cent) of the production of the United States and over 12 per cent of the entire production of the world, is the equivalent of only 1.7 or 1.8 times the coal burned on the Pacific coast of North America alone. It would appear from this that the supply of fuel petroleum must increase very much before it will be possible for petroleum to make much greater inroads into the coal market without ultimately causing a reactionary advance in prices.

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[a] Rept. U. S. Naval "Liquid Fuel" Board, 1904, p. 416.

## COMPETITION WITH IMPORTED COAL.

The following districts in Alaska may produce coal either for local use or for export: Bering River, Matanuska River, Cook Inlet, Alaska Peninsula and adjacent islands, Yukon River, Seward Peninsula, and Cape Lisburne. The coal which is now being shipped to Alaska is derived from the following sources: Vancouver Island, Puget Sound, Australia, and the Appalachian region. Alaska coal will not only have to compete with these at home, but, if it seeks a more extended market, will also meet these coals on Puget Sound, at San Francisco, and in the navy-yards of the Pacific, and will also compete to some extent with the coal now being mined in California and Oregon. It is consequently important to compare the character of the Alaska coals with that of all those with which they may come into competition. This may be done by inspecting the following tables of analyses, which are the best available substitutes for actual practical tests and which may be relied on to give a close approximation to the quality and value of the coal:

*Average composition and character of Alaska coals.*

| District and kind of coal. | Moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Fuel ratio. |
|---|---|---|---|---|---|---|
| Bering River, anthracite, average of 7 analyses [a] | 7.88 | 6.15 | 78.23 | 7.74 | 1.30 | 12.86 |
| Bering River, semianthracite, average of 11 analyses [a] | 4.76 | 13.27 | 74.84 | 7.12 | 1.51 | 5.68 |
| Matanuska River, anthracite, 1 sample [b] | 2.55 | 7.08 | 84.32 | 6.05 | .57 | 11.90 |
| Matanuska River, semibituminous and bituminous, average of 16 analyses [b] | 2.71 | 20.23 | 65.39 | 11.60 | .57 | 3.23 |
| Matanuska River, lower grade bituminous, average of 4 analyses [b] | 6.56 | 35.43 | 49.44 | 8.23 | .37 | 1.40 |
| Cape Lisburne, semibituminous, average of 3 analyses [c] | 3.66 | 17.47 | 75.94 | 2.92 | .96 | 4.46 |
| Cape Lisburne, bituminous, average of 12 analyses [c] | 9.46 | 38.42 | 46.83 | 5.24 | .38 | 1.21 |
| Yukon River, bituminous, average of 9 analyses [d] | 4.69 | 32.05 | 55.89 | 6.97 | ........ | 1.85 |
| Yukon River, lignite, average of 9 analyses [d] | 11.89 | 41.11 | 40.82 | 6.20 | ........ | .89 |
| Alaska Peninsula, bituminous, average of 5 analyses [e] | 2.34 | 38.68 | 49.75 | 9.22 | 1.07 | 1.30 |
| Kachemak Bay, lignite, average of 6 analyses [f] | 19.85 | 40.48 | 30.99 | 8.68 | .35 | .77 |
| Seward Peninsula, lignite, 1 sample [g] | 24.92 | 38.15 | 33.58 | 3.85 | .68 | ........ |
| Southeastern Alaska, lignite, average of 5 analyses [h] | 1.97 | 37.84 | 35.18 | 24.23 | .57 | 1.02 |

[a] P. 74.

[b] P. 97.

[c] Brooks, A. H., Trans. Am. Inst. Min. Eng., vol. 36, 1905, p. 692.

[d] Collier, A. J., Bull. U. S. Geol. Survey No. 218, 1903, p. 64.

[e] Average obtained from published and unpublished analyses by the U. S. Geol. Survey.

[f] Stone, R. W., Bull. U. S. Geol. Survey No. 259, 1905, p. 171.

[g] Moffit, F. H., Bull. U. S. Geol. Survey No. 247, 1905, p. 67.

[h] Dall, W. H., Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 783.

*Average composition of Pacific coals.*

| District and kind of coal. | Moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Fuel ratio. |
|---|---|---|---|---|---|---|
| British Columbia, Crows Nest Pass, average of 10 analyses [a, b] | 1.09 | 21.07 | 70.54 | 7.29 | 0.37 | 3.35 |
| British Columbia, Comox, average of 9 analyses [b, c, d] | 1.18 | 28.41 | 62.91 | 7.49 | 1.54 | 2.21 |
| British Columbia, Nanaimo, average of 6 analyses [b, c, e] | 2.12 | 34.07 | 55.94 | 7.93 | .64 | 1.64 |
| Washington, Wilkeson, average of 7 analyses [f, g, h] | .92 | 27.15 | 61.82 | 10.11 | 1.42 | 2.28 |
| Washington, Cokedale, average of 3 analyses [f, h] | 1.27 | 28.04 | 62.30 | 8.39 | .34 | 2.22 |
| Washington, Blue Canyon, average of 3 analyses [f, g, i] | 1.62 | 32.63 | 60.47 | 5.28 | .53 | 1.85 |
| Washington, Carbonado, average of 15 analyses [g, i] | 1.67 | 33.11 | 56.74 | 8.48 | .94 | 1.71 |
| Washington, Roslyn, average of 9 analyses [b, f, g, h, i] | 2.68 | 34.37 | 52.75 | 9.87 | .24 | 1.53 |
| Washington, Franklin, average of 5 analyses [f, g] | 3.22 | 35.40 | 53.82 | 7.55 | .15 | 1.52 |
| Washington, Renton, average of 10 analyses [g, h] | 4.48 | 36.01 | 51.17 | 8.23 | .61 | 1.42 |
| Washington, Newcastle, average of 5 analyses [f, g] | 7.51 | 37.69 | 48.94 | 5.86 | .48 | 1.30 |
| Washington, Black Diamond, average of 4 analyses [f, h] | 4.44 | 40.50 | 51.73 | 3.33 | .44 | 1.28 |
| Oregon, Coos Bay, average of 4 analyses [f] | 10.41 | 46.15 | 36.85 | 6.59 | 1.02 | .80 |
| California, average of 10 analyses [j] | 11.32 | 45.09 | 35.91 | 7.68 | ........ | .80 |
| Japan, average of 8 analyses [k] | 2.62 | 42.49 | 50.07 | 4.82 | .92 | 1.18 |
| Philippines (Cebu), average of 9 analyses [l] | 14.00 | 31.08 | 50.53 | 4.85 | ........ | 1.64 |
| Philippines (Batan), average of 5 analyses [l] | 13.57 | 36.91 | 44.92 | 4.60 | ........ | 1.22 |
| New South Wales, southern, average of 21 analyses [m] | .97 | 23.10 | 56.26 | 10.67 | .46 | 2.83 |
| New South Wales, western, average of 13 analyses [m] | 1.87 | 31.49 | 52.61 | 14.03 | .63 | 1.67 |
| New South Wales, northern, average of 77 analyses [m] | 1.92 | 35.09 | 54.08 | 8.91 | .54 | 1.62 |

[a] Ann. Rept. Geol. Survey Canada, vol. 3, pt. 2, 1887-88, pp. 12 T-15 T.
[b] Ann. Rept. Minister of Mines, British Columbia, for 1902, p. 262 H.
[c] Ann. Rept. Geol. Survey Canada, 1872-73, pp. 76-78.
[d] Ann. Rept. Geol. Survey Canada, 1876-77, p. 468.
[e] Ann. Rept. Geol. Survey Canada, 1882-84, p. 37 M.
[f] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, pp. 490, 501, 510.
[g] Ann. Rept. Washington Geol. Survey, vol. 2, 1902, p. 270.
[h] Rept. State Inspector of Mines, Washington, 1901-2.
[i] Ann. Rept. Washington Geol. Survey, vol. 1, 1901, Pls. XXV, XXVII.
[j] Geology of California, vol. 3, p. 48.
[k] Outlines of the Geology of Japan, Imperial Geol. Survey of Japan, 1902, p. 190.
[l] The Coal Measures of the Philippines (Report to the United States military governor in the Philippines), War Department, 1901, pp. 178-181, 256-259.
[m] Mineral Resources of New South Wales, 1901, pp. 324-348.

*Average composition of eastern coals.*

| District and kind of coal. | Moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Fuel ratio. | Remarks. |
|---|---|---|---|---|---|---|---|
| Pennsylvania, anthracite, average of 9 analyses.[a] | 3.39 | 3.81 | 83.79 | 8.42 | 0.59 | 22.33 | Domestic coal. |
| Loyalsock, Pa., semianthracite, average of 4 analyses.[a] | 1.49 | 11.07 | 78.88 | 7.69 | .86 | 7.13 | Do. |
| Pocahontas, W. Va., semibituminous, average of 38 analyses.[b] | .73 | 17.43 | 77.71 | 4.63 | .62 | 4.46 | Steam and coking coal. |
| Georges Creek, Md., semibituminous, average of 53 analyses.[c] | .70 | 18.81 | 72.96 | 7.26 | 1.01 | 3.89 | Steam coal. |
| Connellsville, Pa., bituminous, average of 3 analyses.[d] | 1.07 | 32.70 | 60.28 | 5.95 | .81 | 1.84 | Coking coal. |
| Fairmont, W. Va., bituminous, average of 63 analyses.[e] | .75 | 38.16 | 54.63 | 6.45 | 2.30 | 1.43 | Coking and steam coal. |

[a] Ann. Rept. Geol. Survey Pennsylvania, 1885, pp. 313, 318.
[b] Rept. Geol. Survey West Virginia, vol. 2, 1903, pp. 695, 696, 700.
[c] Rept. Maryland Geol. Survey, vol. 5, 1906, pp. 631-633.
[d] Rept. Geol. Survey Pennsylvania, vol. MM, 1879, pp. 21-22.
[e] Rept. Geol. Survey West Virginia, vol. 2, 1903, p. 209.

It may be seen from these tables that the anthracite from Matanuska and Bering rivers has no equivalent on the Pacific coast, and that it compares favorably with the Pennsylvania anthracite. It ought to be put into the San Francisco and other Pacific coast markets at a cost far below that of eastern coal, in which case it should have no difficulty in entirely supplanting the latter.

The Bering River semianthracite and part of the semibituminous coal from Matanuska is also better than anything that is being mined in the West. These coals are the equivalent of the Pocahontas, New River, and Georges Creek coals of the East and are eminently adapted for use on war ships and for other purposes for which a high-grade, pure, "smokeless" steaming coal is required, and for these purposes will command a considerably higher price than any coal now being mined on the Pacific coast, or if offered at equal prices should readily drive the latter from the market.

Part of these coals will produce an excellent quality of coke—better, in fact (except possibly in content of phosphorus, regarding which no data are available), than coke which can be produced from any of the Washington or Vancouver Island coals and equal to the coke from Crows Nest Pass. If an important smelter industry grows up in Alaska, as now seems possible, the Alaska coking coals should have the advantage both of quality and of transportation.

The coals from other known Alaska fields than these are so situated or are of such quality that they can find markets only where excessive rates on outside coals give them an advantage—that is, their markets must be local and probably small.

# LODE MINING IN SOUTHEASTERN ALASKA.

By F. E. and C. W. WRIGHT.

## INTRODUCTION.

In southeastern Alaska the last year has been one of unusual activity in mining exploration and development. In general, operations have fortunately been concentrated on limited areas with the result that several new mines now promise well as future ore producers.

Of the five mining recording districts into which southeastern Alaska is divided the Juneau and Ketchikan districts have made the most decided advances, with the Skagway, Wrangell, and Sitka districts following in the order named. It is the purpose of this paper to give a brief description of the recent economic developments, introduced by a few general statements on the geography and geology.

## GEOGRAPHY.

The geographic position of southeastern Alaska is unique in many ways. Bordered on one side by the Pacific Ocean and on the other by the Coast Range, it extends as a narrow strip northwestward from Portland Canal for over 500 miles to Mount St. Elias, near Yakutat Bay. It includes a mainland belt with an outlying archipelago broken by narrow, deep salt-water channels or fiords.

The timber resources of the country are considerable and form one of its most permanent assets. Hemlock, spruce, and yellow and red cedar constitute the lumber of economic value. The Government has wisely added several of the large islands in this portion of Alaska to its forest reserve, thereby insuring intelligent use of the timber at the present time and preservation and protection for the future. Though the establishment of this new forest reserve appears in some respects to have placed a restraint on the prospector, yet the provisions of the law in regard to mining within the reservation are liberal.[a]

## GEOLOGY.

The geologic structure of southeastern Alaska has had a marked influence on its topographic development. In a broad way the consideration of its structural features resolves itself into that of the Coast Range granite belt, with the outlying granite masses and of the intruded rocks (Pl. XI). The backbone of the Coast Range consists of an immense granite belt many hundred miles in length and 30 to 100 miles in width. Similarly the cores of several of the islands are composed of intrusive granite masses. The intruded strata are arranged in long bands striking usually parallel to the trend of the Coast Range in a northwesterly direction and dipping either northeast or less frequently southwest at variable angles. They consist of slates, sandstones, conglomerates, limestones, and other sedimentary rocks with intercalated tuffs and intrusive bands of greenstone, all of which are folded and faulted and so profoundly metamorphosed that their original character has often been entirely obliterated. Of these various rock types the most prominent perhaps

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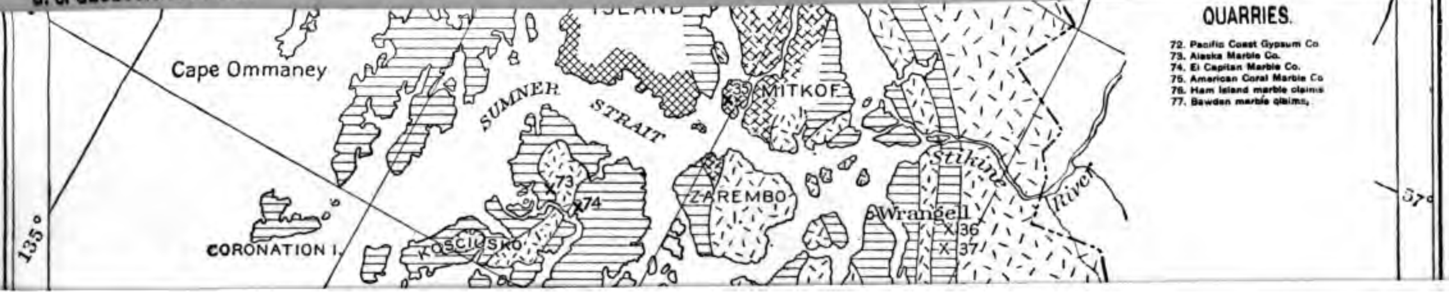
[a] The Forest Service of the Department of Agriculture has issued a book of regulations and instructions—The Use of the National Forest Reserve—a copy of which can be secured from the forest officer at Ketchikan, or from the Secretary of Agriculture at Washington, D. C.


135°
Cape Ommaney
CORONATION I.
KOSCIUSKO
SUMNER STRAIT
ISLAND
73
74
ZAREMBO
35
MITKOF
Wrangell
36
37
Stikine River
57°
QUARRIES.
72. Pacific Coast Gypsum Co
73. Alaska Marble Co.
74. El Capitan Marble Co.
75. American Coral Marble Co
76. Ham island marble claims
77. Bawden marble claims,

are the greenstones, a field name for highly metamorphosed and usually fine-grained rocks of a greenish cast, which range in composition from altered andesite and andesitic tuffs to basalts and equivalent granular varieties. Intrusive dike rocks occur frequently and have been injected at different periods.

During the past summer special study was made of the fossil-bearing strata of southeastern Alaska by E. M. Kindle, in company with one of the writers. The results of this investigation show that the geologic column extends from the Silurian rocks upward. The Paleozoic formations constitute the greater portion of the sedimentary rocks, and are made up principally of limestones and schists. These strata have suffered in general such alterations that their fossil content has been effaced, and paleontologic evidence was rarely found.

The Mesozoic formations, though folded and tilted on edge, are only slightly metamorphosed and rarely altered to schist. Slates, graywacke, and conglomerates are the essential rock types, though limestone was also observed. The areal distribution of the Mesozoic beds is relatively small. Tertiary beds have been deposited locally on Admiralty and Kupreanof islands, and at these places are comparatively flat lying and unaltered. They are made up of shale, sandstone, and conglomerate beds, and are coal bearing.

## ORE DEPOSITS.

Taken as a whole the ore deposits of southeastern Alaska are of low grade, though there are many exceptions to this rule. Mineralization is widespread, metallic sulphides occur disseminated throughout most of the beds, but concentration into workable deposits is relatively rare.

The determination of the origin of the ore deposits is of direct commercial importance and it is unfortunate that the field studies have not progressed far enough to permit a solution of the problem. While this phase of the subject will not be discussed here, it can be stated that the accumulation of observations bears out the suggestion made in previous reports[a] that there is a genetic relation between the ore bodies and the intrusives.

### GOLD.

Gold occurs not only in quartz ledges, but also in igneous dikes and altered bedded rocks. It is a frequent accessory constituent of copper deposits. The greater number of the ore bodies are low grade in character and are often passed over by the gold seeker, whose object is to find rich ledges or pockets of ore which will yield him quick returns with a small amount of labor.

In 1905 placer gold was mined at only two localities—on Porcupine Creek,[b] in the Skagway district, and on Gold Creek, in the Juneau district.

#### JUNEAU DISTRICT.

The mainland strip extending from Juneau to Berners Bay is doubtless the richest gold-bearing area in southeastern Alaska yet discovered. Developments within this mineral belt have made rapid progress during the last year and future improvements will materially increase its present gold production.

##### BERNERS BAY.

In the Berners Bay region members of the slate-greenstone series, together with intrusive granite and diorite belts, constitute the exposed rock types (Pl. XI). The Coast Range intrusive belt lies to the east, and branching from it is a narrow wedge-shaped mass of diorite which has invaded the sediments and is the locus of the principal deposits. At the head of Berners Bay this diorite mass is 2 miles wide, while 3 miles north of Comet it is cut off by Lynn Canal and narrows to half a mile.

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[a] Brooks, A. H., The Ketchikan mining district, Alaska: Prof. Paper U. S. Geol. Survey No. 1, 1902. Spencer, A. C., The Juneau gold belt: Bull. U. S. Geol. Survey No. 225, 1903, pp. 28-42.

[b] Wright, C. W., Porcupine placer district, Alaska: Bull. U. S. Geol. Survey No. 236, 1904.

Three types of mineral deposits may be distinguished in this district, namely, fissures or veins, fractured zones, and lodes along the contact of intrusive rocks. Of the first class the Comet, Northern Bell, and Savage veins are the most important. Mining at these localities has shown usually solid bodies of quartz 2 to 10 feet in width and striking in a northerly direction, with steep dips to the east. The diorite walls are ordinarily free and well defined and often show the presence of soft gouge. Along the direction of the strike the quartz veins gradually wedge out and the continuation of the fissures is defined by a chlorite schist, evidently developed from the diorite by slipping along the fissure plane. In the veins the gold occurs both native and associated with sulphides, and the larger portion of it can be recovered by amalgamation. The values are not always uniformly distributed in the ledges and often follow shoots or are segregated in pockets.

Deposits of the second type are exposed at the Kensington and Eureka mines and are essentially fractured zones in the diorite which have been filled with intersecting veinlets of quartz, carrying sulphide minerals, the latter frequently penetrating the diorite itself.

Deposits of the third type, which resemble the fractured zones of the second class, occur either along the contact of the diorite and greenstone, as exposed at the Johnson lode, or of the diorite and slate, as at the Greek Boy lode. At these localities the contact zone is penetrated by many quartz veinlets and in or near these the gold values are found.

The Comet mine, which was operated from 1894 to 1901, is one of the earliest locations in this area and has been the greatest gold producer. It belongs to the Berners Bay Mining and Milling Company and is located at 2,350 feet elevation, not far below the divide between Sherman and Johnson creeks. At 1,900 feet elevation a crosscut tunnel 1,875 feet in length has been driven to the Comet vein, from which point an aerial tram 5,000 feet long extends to a 40-stamp mill on Sherman creek. At 2,600 feet elevation two parallel veins are exposed on the surface, but only the latter, the foot-wall vein, has been mined in depth. It is a well-defined quartz-filled fissure, which varies from 2 to 8 feet in width in the upper levels, while in the lower levels masses of the country rock are included in the vein, thus forming a wider ore body of lower grade. The continuation of this vein to the north is faulted and, though its direct extension has not been found, it seems probable that the Northern Bell vein may be the same, as its character and the values contained are identical.

From the main level to the surface the Comet vein has produced over 50,000 tons of ore, which yielded a total of about $460,000. From this ore 87 per cent of its gold contents were recovered in bullion and 5 per cent in the concentrates. Future mining must be carried on below the main level and may be hampered by the inflow of water along the fault plane which follows the gulch between this mine and the Northern Bell.

The Northern Bell mine, the property of the Northern Bell Gold Mining Company, was operated in 1896 and 1897 and produced during that time nearly 23,000 tons of ore, which yielded 78 per cent of the gold values in bullion. The ore body, as already noted, resembles the Comet vein to the south.

The Bear mine, the oldest of the group of claims belonging to the Berners Bay Mining and Milling Company, has been opened at 1,340 feet elevation by a 1,100-foot tunnel, in which two well-defined quartz veins are crosscut at points 300 and 550 feet from its mouth. From drifts extending several hundred feet in each direction along these veins 5,500 tons of quartz ore were mined during the years 1895–1897. The ore was much lower in value than that from the Comet mine and only 62 per cent of the gold was recovered in bullion.

During the years 1897 to 1900 the Kensington ore body, controlled by the Berners Bay Mining and Milling Company, was opened by extensive surface and shallow underground workings. It is situated at a point 2,900 feet above tide water, and from it nearly 12,000 tons of ore are said to have been mined. The following distribution of values was reported from the mill returns: Bullion 5 per cent, concentrates 62 per cent, and tailings 33 per cent. This ore is totally unlike the Comet ore, and hence must be treated by different methods to prevent the great loss in the tailings.

In 1904 a crosscut tunnel starting at 1,800 feet above sea level was completed, and at a point 1,950 feet from its mouth undercuts the Kensington lode. The ore body where intersected, 1,000 feet below the surface croppings, has been explored by 640 feet of drifting, and the lode has been shown to have an elliptical cross section, 80 feet in width and 160 feet in length. As there are no definite walls to the ore body its limits are determined by the costs of extraction and a decrease of these costs will increase the limits of profitable mining, and hence the dimensions of the workable deposits. Although the Kensington lode is probably continuous from the lower openings to the surface no definite statements can be made regarding its uniformity and value between these points.

The Eureka lode, which has some features in common with the Kensington, has been prospected at the outcrop and has also been crosscut by the Kensington tunnel at a depth of 400 feet and 1,300 feet from the mouth of the tunnel. Like the Kensington its limits are determined by mining costs, as the walls are not well defined, but where crosscut it is about 30 feet wide. The values from the ore are reported to be exceptionally high for this character of deposit.

Other properties controlled by the Berners Bay Mining and Milling Company are the Ophir and Seward groups of claims. The mineral deposits on these properties are veins of quartz which have been prospected only and are reported not to carry high gold values.

The Johnson or Northern Light mine is situated about half a mile to the east of the Kensington mine, at 2,600 feet above tide, and is the principal holding of the Nowell Mining and Milling Company. Developments on this property are limited to surface prospecting along a gulch from about 2,600 feet to the crest of the hill at 3,300 feet above tide. Owing to the accumulations of slide rock in this gulch it is difficult to determine the true extent of the ore body. Mineralization appears to follow the contact of the diorite and greenstone, along which a fracturing and in places faulting has occurred. Quartz is more abundant in this lode than in the Kensington, but the ore body is less regular and will require more development to determine its extent and value. An extension of the Kensington tunnel has been proposed to mine this ore body.

The Portland Alaska Gold Mining Company operated the property known as the Horrible mine from 1897 to 1898 and again in 1901. The mine workings are located at an altitude of 2,200 feet on the north slope of Sherman Creek and are connected, by an aerial tramway 2 miles in length, with a 10-stamp mill on the shore of Lynn Canal. The ore body consists of a quartz vein in the diorite country rock. It has been opened by a main drift for a length of 400 feet and averages 5 feet in width. Nearly 1,000 feet of tunneling and drifting have been accomplished and considerable ore stoped out. A total of 500 tons of ore is reported to have been mined, yielding about $1,500 in gold.

The Ivanhoe mine was purchased in 1897 by the Mellen Mining Company and operated by it at intervals up to 1903. Four quartz veins have been explored, though the main workings are confined to one of the upper veins outcropping at 2,400 feet elevation. A crosscut tunnel penetrates the foot wall of basic diorite for 185 feet, and from this point a drift follows the ore body in a southerly direction for 850 feet, over which length the quartz vein averages 5 feet in width. From this tunnel a 3,000-foot cable tram connects with a gravity tramway 2,700 feet long, which leads to the mill on the north side of Sherman Creek, 1¼ miles from the wharf at Comet. The mill is equipped with 20 stamps and 8 Frue concentrators. A total of 3,000 tons of ore is said to have been mined and milled from this ledge, which gave a yield of about $7,000.

The Jualin mine, now owned by the Jualin Mines Company, is situated at an altitude of 730 feet on Johnson Creek, 4 miles from the tide flats of Berners Bay. During the years 1896 to 1900 this property was worked continuously, and again in 1903, but operations were closed at the end of that year and not resumed until May, 1905, since which time 40 men have been employed.

The mineral deposits consist of three distinct and unlike ore bodies inclosed in the diorite country rock about 1,200 feet from its contact with the slates and greenstones to the west. Of these the foot-wall vein carries the highest values and is the one which is being mined at present. It is a well-defined quartz vein which on the main working level, 170 feet below the adit level, has been exposed 400 feet in length and averages 5 feet in width. Sixty feet below the adit level its length is only 100 feet and its average width 2 feet. Both to the north and the south the vein narrows to a fissure filling a few inches wide. The gold values are uniformly distributed throughout this vein and are essentially in a free state. Pyrite and chalcopyrite, with malachite and azurite as alteration products, are the accompanying minerals. A second and much larger ore body lies to the northwest of the footwall vein and has an average width of 10 feet throughout its length of 400 feet. Several thousand tons of ore have been mined from this ledge in past years, but its value is said to be too low to warrant further extraction. The third or hanging-wall ore body is to the southeast of the first mentioned. It is, however, poorly defined and consists of an irregular fissure filled with mineralized diorite fragments and quartz stringers. The lode is exposed in a drift for 150 feet in length and from 2 to 6 feet in width. Its gold content is somewhat greater than that of the second ore body.

The ore is treated in a 10-stamp mill equipped with Frue concentrators and operated by water power. A tramway 5 miles in length is being built from the mine to a point opposite deep water near the head of Berners Bay.

Adjoining the Jualin mine to the northeast is the Indiana group, the property of the Alaska Gold Mining Company. The claims were located in 1896 and were believed to be on the extension of the Jualin and Comet veins. Three tunnels have been driven into diorite country rock on the west slope of Johnson Creek. The main tunnel, at 850 feet elevation, is 1,100 feet in length, with 500 feet of drifting to the north and south near its face. Sixty feet from its entrance the tunnel crosscuts a narrow belt of quartz stringers carrying chalcopyrite and pyrite which yielded a small amount of ore. No other lodes were exposed by this lower tunnel or in the two entering at points 100 and 200 feet above it.

A 10-stamp mill, together with a water-pipe line several thousand feet in length, was constructed on Johnson Creek below the lower tunnel, but never operated.

Many other prospects are located within the Berners Bay district, and some of the ore bodies exposed are worthy of extended development. Those which have received the most attention are the Fremming and the Falls groups, located on Johnson Creek below Jualin mine, and the Little Johnson, the Gold King, and the Medicine Bird groups of claims at the head of Johnson Creek. On Sweney Creek prospecting has continued on a wide quartz lode with satisfactory results. The construction of a stamp mill and further underground developments are planned for 1906.

The properties of the Greek Boy Mining Company are located 4 miles from deep water on a creek tributary to Berners Bay River. The ore body exposed consists of a band of mineralized slate 8 to 20 feet wide cut by quartz stringers, some of which are a few feet in width. The lode follows the contact of the diorite intrusive rock which forms the foot wall, strikes N. 45° W., and dips 85° SW. Many openings have been made along this contact, but most of the prospecting has been confined to one claim on which two tunnels have been driven, each following the lode for several hundred feet. The sulphide minerals of the deposit are irregularly distributed and appear to be small in amount. No work beyond that required by law was done in 1905.

On the south side of Berners Bay prospecting was advanced on various mine locations, including the Berners Bay claim. In Echo Inlet assessment work was completed on the California and Gold Standard groups and encouraging results were reported.

### YANKEE BASIN.

The area in and about Yankee Basin was the scene of much mining activity last summer. Developments were continued on various properties and several new and promising ore bodies were discovered.

The Julia group of claims is located in the upper portion of the basin at altitudes of 2,000 to 2,800 feet. On this group six ore bodies have been exposed, namely, the Cascade, a 6-foot quartz vain; Julia No. 1, a 12-foot lode of mineralized schist and quartz; Julia No. 2, an 8-foot lode of the same character; Dividend, a 12-foot lode of mineralized black slate cut by quartz stringers; Puzzler, a 14-foot lode of quartz and schist carrying mineral; and Noonday, a 6-foot quartz vein. The country rock is graphitic slate and schist, lying 1 mile east of the Coast Range intrusive belt and striking approximately parallel with its lines of contact, or N. 50° W., with a dip to the northeast at steep angles into the mountain.

At the time of visit developments were in progress on the various deposits, but no systematic work was being done. A crosscut tunnel is proposed which will start below the Dividend lode and undercut all the exposed ore bodies and thus determine their character in depth if they are continuous to this level.

The Rex claim, on which a rich stringer or pocket of ore, said to have yielded $3,000, was opened in 1903, has received no attention during the past two years.

The property of the Bessie Gold Mining Company is located at 1,400 feet elevation, 2½ miles by wagon road from Yankee Cove. The ore body is a well-defined quartz vein inclosed in the greenstone country rock and striking N. 75° E., with a steep southerly dip. The vein is apparently persistent for 1,600 feet in length and varies from 1 to 6 feet in width. Arsenical pyrite is the principal sulphide, though pyrite also occurs and specimens of free gold are not uncommon. Two tunnels 360 and 124 feet in length and a shaft 161 feet deep constitute the developments. Except a few tons for testing purposes no ore has been shipped and the property has been idle during the last two years.

A group of claims southeast of the Bessie mine belongs to the Alaska-Washington Gold Mining Company. Two parallel veins, similar in their general features and separated by 600 feet of slate and greenstone country rock, form the mineral deposits. Only one of these has been explored. It is exposed at various points for a distance of nearly 3,000 feet, with an average width of 3 feet. The mine workings, which were completed in 1902, consist of 500 feet of tunneling, a 70-foot raise, and a 30-foot shaft. No important developments have been made since that time.

The Aurora-Borealis group is situated adjacent and below the Bessie mine at 1,000 to 1,400 feet elevation above sea level. The quartz ore body here parallels a contact between black slate and a wide belt of greenstone, which strikes northwest and dips steeply to the northeast. It has been opened by three drift tunnels, each a few hundred feet in length, at altitudes of 1,100 feet, 1,200 feet, and 1,350 feet above salt water. Below these a 5-stamp mill has been erected and connects with the workings by a cable tramway. A wagon road 2½ miles in length runs from the mill to Yankee Cove. At the time it was closed down, several years ago, the mine was reported to have produced a total of $25,000 in gold.

### EAGLE RIVER.

Of the many auriferous quartz ledges which have been discovered within the area about Eagle River only those belonging to the Eagle River Mining Company have been developed sufficiently to warrant description. The property lies on the north side of the river, 7 miles from a wharf at Eagle Cove. Geologically its position is within the belt of slates and greenstones and near their contact with the schists to the northeast, 1 mile southwest of the Coast Range intrusive. The ore body may be described as a connected chain of ore shoots, elliptical in cross section, striking N. 30° W., dipping 50° NE., and pitching northwestward into the mountain at an angle of 30°. They are included in the bands of slate and greenstone country rock, which in places is much shattered, necessitating heavy timbering in both tunnels and stopes. Three such ore shoots are being mined, and average from 5 to 15 feet in width and 25 to 100 feet in length. Though their persistence in depth has not yet been determined, they will probably continue to the limits within which mining will be carried on. Free gold, pyrite, pyrrhotite, chalcopyrite, and occasional specimens of native copper are present in the ore. The developments amount to about 3,000 feet of tunneling and drifting and nearly 1,000 feet of shafts and raises, besides much stoping. Nine hundred feet below the mine and connected with it by a cable tramway is a well-equipped 20-stamp mill. From the mill a horse tram 7 miles long leads to the wharf at Eagle Cove. An average of 50 men were employed at the mine during 1905. Its total production, including that for 1905, is roughly estimated at $250,000.

### PETERSON CREEK.

The Peterson group of claims is situated on the northeast side of Peterson Creek, 4 miles by wagon road from Pearl Harbor. Although prospecting has been done on all the claims, the Prairie claim has been developed most extensively. The ore body is a wide, flat-lying mass of quartz, striking N. 30° W., and inclosed in black slate, with arsenical pyrite as its only sulphide. Several shafts have been started at various points, both on and away from the deposit, but no systematic work has been done.

### WINDFALL CREEK.

Starting from a point on Windfall Creek one-half mile above Windfall Lake, the placer claims of the Detroit Alaska Mining Company extend to the headwaters of the creek. The usual route to the mine workings, which are on claim No. 1, is by wagon road and trail from Eagle Cove, a distance of 7 miles. The gravel deposit under attack is 150 feet in width, 20 feet in depth, and extends for a claim's length above the present workings to a point where it is cut off by a canyon. About 40 per cent of the gravels consist of cobbles and bowlders of granite, greenstone, and quartz, which average from 4 to 8 inches in diameter. No clay strata were observed, though a narrow bed of sand, which is said to be the richest portion of the deposit, occurs 2½ feet above bed rock. The gold itself is hackly and of a dull color and is usually found in a fine state. The bed rock consists of bands of slate and greenstone, the trend of which is followed by the creek. A new hydraulic elevator was installed in 1904 and the water-supply flumes enlarged. This season was exceptionally dry, and actual mining of the gravels could proceed only at intervals. The results obtained, however, when operating were said to be satisfactory. It is planned in 1906 to build a ditch and divert the upper waters of Montana Creek into Windfall Creek, and thus materially increase its present volume of water.

The Smith & Heid group of claims has been located since 1893 at the head of Windfall Creek and small developments made each succeeding year. In 1897 and 1898 a tunnel 125 feet in length was driven to undercut an ore body exposed on the surface, but the results were not satisfactory. Since then assessment work only has been done. The lodes exposed are both quartz and mineralized chlorite schists inclosed the slate-greenstone country rock. Their surface exposures are irregular, and though rich ore occurs it does not appear to be uniformly distributed, and developments have not yet defined any extensive high-grade ore bodies.

### MONTANA CREEK.

At the head of Montana Creek, at an altitude of 2,600 feet, is a basin of considerable area, on the slopes of which the Montana Basin group of claims has been located. The rock exposures at the mouth of the basin are of slate and greenstone, and at its head, or to the east, the schist belt occurs. The ore bodies consist of stringer leads or lodes of mineralized slate cut by many quartz veinlets. Several such lodes have been uncovered which are parallel to the bed-rock structure, besides two narrow but richer quartz veins striking in a northeasterly direction. Four hundred feet of tunneling have been extended at various points on these claims, and the assessment work is done each year. The low values in ore bodies and their distance from salt water has been the chief cause of their retarded development.

Considerable capital has been invested by the Mansfield Gold Mining Company in the development of a group of both lode and placer claims on the south side of McGinnis Creek, an eastern tributary of Montana Creek, but apparently with unsatisfactory results. On the lode claims several stringers of quartz were followed by tunneling and found to be of no value. The placer claims are located on an extensive bench deposit, which contains considerable slide rock from the high cliffs above them and has a large percentage of heavy bowlders and cobbles. Tests made on this deposit have determined that the values are not great enough to warrant further exploitation.

### LEMON CREEK.

The placer mining claims on the gravels of Lemon Creek extend from its mouth to Lemon Creek Glacier, a distance of 6 miles. During the past year careful tests were made on these deposits and the gold content of the gravels found to be very low. In October, 1905, operations ceased, with apparently no prospect of continuation.

At the head of the creek lode claims were located on quartz veins in the schist belt, but the gold values in these are low, and under present conditions are of little importance.

### SALMON CREEK.

The Wagner prospect, on the south side of Salmon Creek near its mouth, is located on a quartz lode which varies in width from a fraction of an inch to 8 feet and follows the contact of altered slate and greenstone, striking N. 20° W. and dipping 40° NE. The ore contains arsenical pyrite, pyrite,and chalcopyrite, also some galena and sphalerite. Nearly 100 feet of tunneling have been completed, and during the summer a small testing mill was placed on the property.

### GOLD CREEK.

In view of the detailed report on this area by A. C. Spencer,[a] already in press, only a brief mention will be made of the mine developments during the last year.

Developments at the Ebner mine have progressed without interruption, and an average of 15 men has been employed throughout the year. The ore bodies are mineralized diorite dikes cut by quartz gash veins, adjacent to which the rock is penetrated by auriferous sulphides. The total underground developments amount to nearly 4,000 feet of tunneling and drifting, besides the large stopes. It is reported that the total amount of ore milled through the 15-stamp mill on the property has been 80,000 tons.

As the greater portion of the ore is free milling, amalgamation is the only recovery process employed. Concentration of the ore was originally a feature of the reduction plant, but the value of the concentrates was found to be insufficient to pay the costs of handling, transportation, and smelting. The total power required for mill and mine is estimated to be 125 horsepower, which is furnished by the waters of Gold Creek, often during the entire year.

At the Alaska Juneau mine the mineral deposit is similar to that of the Ebner mine, but here the slate carries sufficient values near its contact with the diorite to make ore, and the occurrence of free gold is more plentiful. The operations of the company have consisted largely of surface investigations of a wide mineralized area on the west slope of Silver Bow Basin. The workings comprise several tunnels which undercut the ore body and are connected by raises with large open cuts or pits, thus permitting economical handling of the ore. The total amount of underground developments aggregates nearly 3,000 feet of tunnels, crosscuts, and raises. The annual report to January 1, 1905, gives a total of 24,915 tons of ore milled through the 30-stamp mill on the property, and a similar amount may be estimated for the present year. The mill was in continuous operation from April to November, the working season of this mine.

A careful sampling of the ore body was in progress during the summer to determine the average value of the ore at the tunnel level. For this purpose a width of 3 feet was mined from the sides of the lowest tunnel which crosscuts the deposit, and the ore thus derived was tested in a 5-stamp mill, which was built at the beginning of the year in the basin below the mine.

The locations of the Alaska Perseverance Company are on the southwestern extension of the mineral belt exposed on the Ebner and Alaska Juneau properties, already described. At this mine preparations for large-scale operations are rapidly being advanced. The Alexander tunnel has been extended to a length of 2,500 feet, and at a point 2,150 feet from its mouth a vertical raise 842 feet in length and 4½ by 12 feet in cross section connects with the surface workings. At various points along the tunnel drifts have been started to investigate the ore body along its strike. In the basin below the mine excavations have been made for a 300-stamp mill, 100 of which are to be in operation by the early spring. A large boarding house and mine office have been built and a compressor and electric plant are under construction. Transportation facilities and a power plant, both of which involve great expense, must still be provided before economical mining can be done.

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[a] The Juneau gold belt: Bull. U. S. Geol. Survey No. 287, 1906.

During the early spring of 1905 a small ledge of rich ore was discovered at the head of Gold Creek, which attracted considerable attention and resulted in the staking of the Bull Consolidated group. This property is located at 2,800 feet elevation on the northeastern edge of the mineral belt. A few sacks of ore were obtained from this ledge for testing purposes, but no development work has yet been done.

Other properties in the Gold Creek area are the Humboldt mine and the Hallam and Boston groups of claims, on which developments have continued during the summer.

The Jualpa Mining Company employed a small crew of men during the summer months and operated its placer property on Gold Creek. A large derrick was erected at the beginning of the season and excavations were made near the mouth of the drainage tunnel. Work, however, at this point is greatly obstructed by masses of slide rock, which compose the greater portion of the gravel wash and often necessitate the use of dynamite. The waters of Gold Creek, which hampered operations in the past, are now controlled by a dam built across the canyon at the junction of Gold Creek and Snowslide Gulch, from which point a flume 4,250 feet in length and 20 by 9 feet in cross section was constructed around the south side of the basin. Operations ceased in October for the season, no gold having been produced. In November excessive water in Gold Creek is reported to have caused a blockade in the drainage tunnel, thus filling the pit, damaging the machinery, and washing away 200 feet of the flume.

The placer deposit in Silver Bow Basin, which was worked from 1895 to 1901, and which during that period yielded nearly $500,000 in gold, was again operated this season. A lease was secured upon this basin deposit by the Silver Bow Hydraulic Mines Company, and operations were begun in July and continued until October. A hydraulic giant, having a 6-inch nozzle under a head of 130 feet, was used and the gravel bank at the mouth of Icy Gulch attacked. The heavy wash of bowlders in this deposit are handled on wheelbarrows or small hand cars, while smaller gravels are hydraulicked into sluice boxes along the bottom of the pit. The gravel bank at this point is 70 feet deep and in it the gold is said to be uniformly distributed, with no marked concentration of values on bed rock. Much mineralized quartz float in large cobbles and fragments is scattered throughout the deposit and is being sorted with the view of milling it at some future date. Ten men were employed during the summer, and the mine returns are reported to have been satisfactory. Early in the spring of 1906 it is proposed to install more hydraulic giants, also elevators, and to increase the water supply.

### SHEEP CREEK.

At Sheep Creek, which empties into Gastineau Channel, 3 miles south of Gold Creek, the principal mines were operated under lease from the spring of 1903 to July 1, 1905, at which time mining ceased.

The mineral belt on which these mines are located is the southern uninterrupted extension of the Gold Creek deposits. The quartz veins occur in well-defined fissures following the structure of the slate country rock and are continuous for only a few hundred feet in length, though as a rule where one vein disappears another is found by driving a short crosscut into the hanging wall.

Other properties within the Sheep Creek drainage area are the Regan mine, the Gould & Curry mine, and the Golden Treasure group. At these there has been no metal production and no mine improvements during the past year.

### DOUGLAS ISLAND.

With the mention of Douglas Island attention is naturally directed toward the Treadwell group of mines. Its geologic features and manner of operation have been discussed at length by A. C. Spencer[a] and by Supt. R. A. Kinzie,[b] to whose papers the reader is referred.

At the Treadwell mine the main shaft has been sunk to a depth of 1,250 feet, from which point a working level is being started. An interval of 200 feet has been established between this level and the one above, the 1,050-foot level, and in the future in these deep workings this distance between levels is to be maintained. On the 1,050-foot level but little change was observed on the ore body, with the exception that the slate horse prominent in the levels above has diminished to a width of 10 feet. The floor level of the open pits is now 600 feet below the surface, but owing to the weakness of the slate foot wall this method of mining can not be employed much farther in depth. The cost of extraction from these open pits at present nearly equals that from the large underground stopes. The annual report for the year ending May 31, 1905, states that a total of 876,234 tons of ore was milled during the year, yielding $1.10 per ton in bullion and $1.18 per ton in concentrates. The total mining and development expense was 96 cents per ton, the milling expense 15 cents per ton, and the cost of treatment of the concentrates 15 cents per ton of ore milled. The total gold production was $2,007,843.

At the Mexican mine developments were extended on the 990-foot and 1,000-foot levels and the shaft extended to a depth of nearly 1,200 feet below the adit level. The annual report for the year ending December 31, 1904, gives a total of 204,237 tons of ore milled, with an average value of $2.97 per ton. The ore yielded $1.39 per ton in free gold and $1.51 per ton from the concentrates, making a total yield of $661,175.

At the Ready Bullion mine the shaft has been continued to a depth of over 1,400 feet on the incline and developments have progressed rapidly on the 1,025 foot and 1,200 foot levels. The yearly report of this mine to January 1, 1905, states that the ore milled amounted to 196,265 tons, yielding $1.07 per ton in free gold and $1.81 per ton in the concentrates, making a total production of $355,312 for the year.

Improvements which are of benefit to all this group of mines consist of a 4,000-foot flume and a 1,200-foot pipe line to bring the waters of Ready Bullion Creek into power-producing use and the building of a large reservoir dam at the headwaters of Fish Creek, the initial point of the long ditch, thus increasing the capacity of the plant during the season of low water.

Several mining properties within the drainage area of Nevada Creek, located many years ago, are attracting renewed interest at the present time. The bed rock exposed up this creek is essentially greenstone and greenstone schist, with intercalated bands of slate at the lower end. Mineralization is general and extends through a belt 1 mile in width beginning about three-fourths of a mile from the mouth of the creek and extending to a point several hundred feet beyond the divide at the head of the creek. Within this belt, which is composed entirely of greenstone schist with occasional massive beds, narrow bands have been defined parallel with the rock structure within which a concentration of metallic minerals has taken place. Where such mineralization occurs the greenstone schist is changed to a talc schist and is then readily recognized by its bleached appearance.

A deposit of this character has been opened on the Red Diamond group of claims, situated at 1,360 feet elevation just below the divide at the head of Nevada Creek. The country rock is a blocky greenstone schist of dark-green color, striking N. 30° E. and dipping 70° SE. A tunnel penetrates the hanging wall for 60 feet, and then, bending to the northwest, cuts diagonally across the ore body for a distance of 50 feet and enters the foot wall for 10 feet. The lode is not over 36 feet in width and is defined on both walls by a narrow gouge seam. Pyrite is disseminated uniformly throughout this altered-schist band; stringers of quartz are present, but do not appear to be any richer in auriferous sulphides. A second and wider though lower-grade ore belt parallels the above a few hundred feet to the east, but no developments have been made on it in depth. Careful investigations were made of these auriferous schists during the past summer to determine their gold contents and milling properties and the results attained have encouraged further developments.

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[a] The Treadwell ore deposits. Bull. U. S. Geol. Survey No. 259, 1905, pp. 69-87.

[b] Methods of mining and milling at Alaska-Treadwell mines: Trans. Am Inst. Min. Eng., vol. 34, pp. 334-386.

A similar mineralized band and a possible continuation of the Red Diamond lode is being investigated on the Mammoth group of claims, situated one-fourth mile below the divide on Nevada Creek. Two crosscut tunnels have been driven at 1,200 and 1,250 feet elevation and in these two mineralized schist bands corresponding to those described above are exposed.

During the last two years little development work has been done on the property of the Alaska Treasure Consolidated Mines Company, which is located below the Mammoth group, and the extent and value of the mineral deposits is still undetermined. A belt of mineralized schist is exposed for over a thousand feet in width up Nevada Creek and some narrow seams of rich ore have been exposed. The belt as a whole carries low values and future mining will probably be confined to bands of ore similar to those exposed on the Red Diamond and Mammoth groups. Subsequent to the time of visit a large crew of men were employed by this company and systematic developments begun.

Other properties on the island are those of the Alaska Atlin Company, the Yakima Mining Company, and the Alaska Consolidated Mining Company. None of these properties are considered of much importance at the present time and no improvements have been made during the last two years.

### ADMIRALTY ISLAND.

A mineral belt on Admiralty Island,[a] extending from Funter Bay to the north end of Seymour Canal, has been explored at two localities this last year, namely, the Mammoth group of claims, 4 miles south of Young Bay, and the Portage group, 2 miles from the head of Funter Bay. At the first-mentioned locality investigations were made on surface exposures consisting of a wide belt of mineralized schist traversed by occasional stringers of quartz carrying pyrite, galena, and sphalerite. The final results obtained from numerous samples are reported to have been unfavorable and developments were discontinued.

At the Portage group assessment work was accomplished on the lower claims located at 400 feet elevation; above them several new locations were made on a belt of mineralized schist, outcropping at 700 feet elevation, 2 miles from the head of the bay. This schist belt, which is exposed across a width of 30 feet, resembles that of the Mammoth group already described. The strike of the mineralized schist at this point is N. 10° W. and the dip 65° NE., the foot wall being defined by an unmineralized and massive greenstone, the hanging wall by a gradual decrease in mineralization.

On Funter Mountain many claims were located during the first part of the year, but no development work was performed during the summer.

Southwest of this mineral belt is the President group of claims, located on the west side of Admiralty Island, 1 mile east of Fishery Point, at an elevation of 250 feet. Three ore bodies composed of quartz and mineralized schist have been discovered here, which are reported to average 30 feet in width and are separated from one another by two narrow belts of barren schist. The ore bodies follow the trend of the country rock, striking northwest and dipping southwest. The sulphides contained are principally pyrrhotite, pyrite, and chalcopyrite, accompanied by small amounts of galena and sphalerite. Several cuts expose the lodes on the surface and a shaft has been started to investigate them in depth.

### MINES SOUTH OF TAKU INLET.

None of the mines along the mainland south of Taku Inlet, namely, at Port Snettisham, Sumdum Bay, and Windham Bay, added to the metal production of the Juneau district during 1905. The two mines at Snettisham and Sumdum, which have been gold producers in the past, have discontinued operations owing to lack of ore. Developments, however, on some of the recent finds have exposed promising ore bodies.

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[a] Wright, C. W., A reconnaissance of Admiralty Island: Bull. U. S. Geol. Survey No. 287, 1906 (in press).

At Taku Harbor and Limestone Inlet, 30 miles south of Juneau, prospecting has been done, and at the latter locality discoveries of gold-bearing quartz veins in a granite country rock are reported.

There are two promising prospects in Port Snettisham—the Bach group, located on a 2-foot quartz vein in the granite country rock, on the north side of Speel Arm, and the Cook group, located on a galena deposit in the schist belt 4 miles east of South Arm and near an inland lake.

Opposite Sumdum, on the north side of Endicott Arm, the Portland group is located on a wide belt of mineralized schist carrying both gold and silver values. On this group no developments beyond the annual assessment work are reported for 1905. A crosscut tunnel 180 feet in length penetrates the mineral-bearing schist.

The Holkham Bay group of claims is situated on the south side of Endicott Arm at 1,800 feet elevation, 1 mile from the shore. Its ore body is a mineralized quartz lode in the schist belt carrying gold, silver, and copper values. Nearly 300 feet of development work has been accomplished and a large tonnage of ore is exposed.

At Windham Bay, 65 miles southeast of Juneau, the many mining corporations which were operating in 1902–3 have either discontinued or abandoned their properties, and at the time of visit, in August, 1905, only the Helvetia Gold Mining Company was operating in this section. The properties of this company include claims in the second basin of Spruce Creek and at the head of the creek. On the lower group a belt of mineralized rock, varying from talc schist to quartz schist and intersected by quartz stringers, is being exploited by three crosscut tunnels having a total length of 300 feet. At the upper group and on the slopes at the head of Spruce Creek lodes apparently of little extent were being prospected.

At Hobart Bay and Port Houghton but little prospecting has been done and no important ore bodies have been reported.

## KETCHIKAN DISTRICT.

In view of the detailed report on the Ketchikan district already published by A. H. Brooks,[a] and the more complete reports on the Wrangell and Ketchikan districts in preparation, only a brief mention will be made of the recent mining developments within these regions.

Gold-bearing deposits have been located at so many different points in this district that only the most promising prospects can be considered here. Although a number of the ore bodies often exhibit beautiful specimens of free gold, their average content is low and they require very economical mining methods to pay at all. Gold tellurides occur sparsely on several claims, but do not form an important ore. From present indications several of the prospects will soon be producing on a dividend-paying basis.

### KASAAN BAY.

In the vicinity of Kasaan Bay the principal gold-bearing veins are located on Granite Mountain near Karta Bay and at Hollis in Twelvemile Arm. (See map, Pl. XI.) Granite Mountain consists of a huge boss of granite 3,500 feet high, intrusive into the surrounding schists and cut off from the black slates on the south by a great fault. Joint cracks and fracture planes in the granite have been filled with gold-bearing quartz veins which are well exposed on the mountain top and can be traced along their trend N. 55°–65° W. for over a mile. The crustified appearance of the quartz indicates its fissure-vein character and argues well for its continuance in depth. The gold is largely free milling and the values are sufficiently high to warrant further development.

The Treasure group of claims, located on the east slope of Granite Mountain, is reached by trail from Karta Bay. The ore body is exposed in a gulch which has resulted from erosion along the quartz-filled fissure. At about 1,400 feet elevation a tunnel over 500 feet in length has been driven along the vein, which varies from 1 to 3 feet in thickness, with an average of about 18 inches, and strikes N. 55° W., with a steep northeasterly dip. Its walls are free and often lined with mineralized gouge, and show slipping striæ which pitch at low angles to the northwest. The vein lies largely in the hanging-wall side of a diabase dike which is frequently decomposed and resembles the "paint rock" of iron-ore miners. The dike has invaded the granite and fills one of the several large fracture or joint fissures. Along the same plane of weakness the mineral-bearing solutions have also deposited their content of quartz with free gold, pyrite, chalcopyrite, and galena. The term granite has been used as a field name, the actual rock being more basic in composition and varying from a medium- to fine-grained diorite to gabbro in which considerable secondary epidote and hornblende appear. A second tunnel, about 160 feet beneath the upper one, has been driven 50 feet along a narrow quartz vein 6 inches in width which may be the continuation of the main lead. Above these workings a second set of veins has been discovered crossing the first and striking N. 15°–20° W. They are also younger than the diabase dikes and crosscut instead of following them. The character of mineralization of the cross veins is not unlike that of the first set. Values, however, are reported to be lower and irregularly distributed.

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[a] The Ketchikan mining district, Alaska: Prof. Paper U. S. Geol. Survey No. 1, 1902.

The remaining claims on Granite Mountain, the Copper group, Cutter, Bendigo, and the Buckhorn group, also several claims on the north foot of the mountain near Salmon Lake, are so similar in character that the above general description applies to the entire group. The details of each claim will be taken up later in the full report.

### HOLLIS.

In the vicinity of Hollis several favorable prospects have been located and a notable amount of development work accomplished in past years. During the last two seasons, however, mining enthusiasm has been at a low ebb and exploration confined to the Crackerjack, Puyallup, Flora and Nellie, and Dew Drop properties. The first two of these are located on gold-bearing quartz veins in a black slate-argillite complex which strikes about northwest and exhibits extensive and complicated folding with some faulting.

The Crackerjack vein has been traced by surface exposures for a mile, and is a well-marked, strong fissure filling, occurring on the hanging wall of a porphyry dike which invades the argillite parallel to its bedding planes. The values occur in shoots, the discovery of which has encouraged the driving of several long drift tunnels. The important minerals are galena, zinc blende, tetrahedrite (gray copper), and pyrite. Of late exploitation has been confined to assessment work alone.

At the Puyallup mine the Crackerjack argillite belt dips to the northeast in consequence of a large anticlinal fold, instead of to the southwest, as at the Crackerjack mine. The ore bodies of both mines are free-milling gold quartz, and have been treated up to the present time in a 5-stamp mill erected on the Puyallup property and connected with Hollis by a tram. Although considerable ore was mined during the past year, developments were not extensive. A new lead, however, has recently been discovered which lies to the southwest and below the original one and may bear some relation to it. A short prospect tunnel, 80 feet long, has been driven along this vein and samples have been taken at several points. In the mine drifts porphyry dikes were observed parallel to the formation and in apparent close relationship to the quartz veins. Faulting in the formation occurs frequently and is a source of trouble in the mine.

The Flora and Nellie group and the adjacent Dew Drop and Rose claims are reached from Hollis by a good trail 8 miles in length. The vein occurs in an altered-porphyry dike and varies from 6 inches to 4 feet in width. It has been followed underground by two tunnels for about 500 feet and shows favorable indications at several points.

The Dew Drop and Rose claims are located on the top of the mountain above the Flora and Nellie and, together with the Commander and other claims, have been worked on a small scale during the last year. Before economic mining operations can be carried on satisfactorily in this neighborhood the transportation facilities must be improved, a costly project, which will not be feasible until the mining value of the deposits has been more satisfactorily demonstrated.

### DOLOMI.

In the vicinity of Dolomi many claims have been staked, abandoned, and relocated. The first discovery, which was made by an Indian boy, was followed rapidly by others, only a few of which have proved of permanent value.

The ore bodies are quartz veins in limestone parallel to the bedding planes and contain as minerals free gold, tetrahedrite (gray copper), galena, zinc blende, chalcopyrite, and pyrite, with quartz and calcite as gangue. On weathering the tetrahedrite and chalcopyrite alter to azurite and malachite and tinge the vein quartz with characteristic blue and green colors. The degree of mineralization is variable within the vein, the rich portions occurring either as ore shoots or irregular pockets.

Of the many deposits which have been discovered the Valparaiso, Amazon, and Golden Fleece veins have been exploited most thoroughly and are best known.

The Valparaiso quartz vein has been traced for a long distance, and a number of claims have been located on it. Its trend is N. 55°–60° W. and dip 35°–45° NE., with considerable variation, due to the folding and flexing of the inclosing marble. At the Valparaiso claim three shafts have been sunk and a maximum depth of 150 feet on the vein attained. Drifts and stopes expose the vein, which carries high gold values in shoots pitching at an angle of 70° E. An adequate tramway with transportation facilities has been installed and will materially reduce the cost of production.

The Amazon and Golden Fleece properties have been idle except for such annual assessment work as was necessary and produced no metal during the past year. The detailed geologic descriptions and relations of these and many other claims will be given in the later report.

### DALL ISLAND.

Dall Island is an irregular strip of land about 40 miles in length, lying southwest of Prince of Wales Island. It is made up essentially of schist, limestone, and occasional narrow belts of granite, all of which have a northwesterly trend and traverse the island at an angle to its principal axis. Prospecting has not been vigorous on this island in consequence of its isolated position, and its coast bordering the Pacific Ocean is known only to a few of the more persistent gold seekers.

The Elk and Virginia claims are located on the south end of Dall Island at Dakoo Harbor, 2 miles northeast of Cape Muzon. The ore bodies are both auriferous quartz veins and belts of schist impregnated with gold-bearing sulphides. On the Elk group, which is situated only a short distance from tide water, two tunnels have been driven 200 and 265 feet in length, at 80 and 450 feet elevation, respectively. The deposit is exposed only in the upper tunnel and by several open cuts. It consists of a belt of decomposed schist, and across a width of 50 feet or more this is reported to carry sufficient values in gold to make low-grade ore. The Virginia group lies to the northwest of the Elk at an altitude of 300 feet, 1½ miles from tide water. Bands of mineralized schist also occur on this property, though the principal ore bodies are quartz veins varying from narrow stringers to veins 10 feet in width. They are exposed by two shafts less than 20 feet in depth and by short tunnels located in the narrow creek canyon. The country rock is a weathered amphibole schist interbedded with narrow bands of crystalline limestone. The gold values are associated with pyrite, chalcopyrite, and galena, and are said to be higher than those contained in the Elk lode.

The Mount Vesta group of claims, a property of the Alaska Industrial Company, is located on the northeastern slope of Mount Vesta, about a mile from Mount Vesta Harbor. The mineral occurs in small seams or veinlets a few inches in width and separated by wide areas of crystalline limestone. The ore is of high grade and composed essentially of tetrahedrite (gray copper) and chalcopyrite with galena and sphalerite. The mine workings are situated between 600 and 800 feet elevation, and consist of open cuts and a tunnel 80 feet in length. Many other prospects have been located along the east coast of Dall Island, though no improvements of importance have been made on them.

### GRAVINA ISLAND.

The Gold Stream group of claims, generally known as the Miller mine, is situated close to tide water on the east side of Gravina Island, about 3 miles from Ketchikan. The surrounding rocks are principally schistose greenstones (Pl. XI). Mineralization has followed certain bands of this schist country rock, impregnating it with auriferous sulphides and altering it to a talcose and siliceous schist. Two lodes of this character averaging 6 and 40 feet in width have been opened by developments. On the smaller or easternmost lode a shaft 100 feet deep has been sunk, from which 300 feet of drifting have been extended and about 1,300 tons of ore mined. At the upper, larger lode a 50-foot shaft has been sunk and its surface exposures investigated by trenches. A 5-stamp testing mill equipped with a concentrating table is on the property, and encouraging results are reported.

### REVILLAGIGEDO ISLAND.

At George Inlet, which forms one of the deep-water fiords on the southwest side of Revillagigedo Island, several prospects have been discovered which give promise of future value if properly developed. Near the entrance of the inlet the Surprise group of claims has been located on several low-grade gold-bearing veins. Adjoining these claims on the north is the Londevan group of claims, originally known as the Telegraph group. At its south end six parallel quartz veins occur, striking north and south with the black argillite country rock and dipping at low and variable angles to the northeast. They can be followed along the surface for several thousand feet and vary from 1 foot to 5 feet in thickness. They are said to carry high silver and low gold values. Pyrite, galena, and zinc blende, with quartz and calcite as gangue minerals, are the most important minerals contained in the veins. At the north end of the property the entire series of veins apparently merges into one huge quartz vein, which is of low grade and somewhat different in character.

The Sea Level mine and adjoining properties are located near the head of Thorne Arm, a bay south of George Inlet. Several years ago mining developments were pushed vigorously at the mine and notable improvements made.[a] Since 1903, however, assessment labor only has been done and at the time of visit the property was idle. Several of the properties in this vicinity have good free-gold surface showings and may prove valuable if properly developed.

### CLEVELAND PENINSULA.

Helm Bay fills a deep indentation on the southwest end of Cleveland Peninsula and follows closely the structural lines of the underlying rocks. On the east side of the bay a wide belt of folded argillites and altered slates is exposed, while on its west side is a complex of greenstone schists, trending parallel to the shore line and composing the mountain ridge, 1,000 to 2,500 feet in elevation, to the east. These schists contain the only workable deposits which have been discovered on the peninsula. Mineralization is widespread in the schist series and low values in gold are not uncommon. Local rich pockets of gold-bearing quartz have been discovered at several points and mined with great activity for a short time. Of late years, however, little work has been accomplished on the peninsula, the attention of prospectors having been directed to other and newer camps. Sufficient labor, however, has been expended on these veins to show that they are a mining possibility and that the average content of the veins should be emphasized rather than the occurrence of rich and alluring bonanzas. The gold occurs both as free gold and with pyrite, also in small quantities as gold telluride. The chief prospects of the bay are the Gold Standard group, the Gold Mountain group, the Alexandria, the Old Glory, the Starry Banner, the Last Chance, and the former Keystone group, which has been relocated under a new name. The total production of these claims the last year has not been enough to rank them with ore producers, and their specific description is reserved for the more complete report.

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[a] Brooks, A. H., The Ketchikan mining district, Alaska: Prof. Paper U. S. Geol. Survey No. 1, 1902, pp. 66-68.

### UNUK RIVER.

Unuk River is one of the few large streams in southeastern Alaska, and is very difficult to navigate even in a small boat. It rises about 55 miles from the head of Burroughs Bay, in Behm Canal, and traverses the entire granite portion of the eastern Coast Range. A low divide connects its head with a branch of Iskoot River and thus serves as an easy entrance way into the interior of British Columbia. The upper 25 or 30 miles of the river drain the schist-argillite belt lying east of the Coast Range granite, which is characterized along its entire extent from British Columbia to the Skagway district by good silver- and gold-bearing veins. At the head of Portland Canal, on several of the Stikine River tributaries, especially Clearwater River, in the Atlin district and still farther north, this belt is known to carry both placer deposits and quartz ore bodies. It has long been known that similar deposits occur in the Unuk River region, and recently a company began the construction of a wagon road from salt water along the northwest bank of Unuk River to a group of claims 42 miles inland across the boundary in British Columbia territory. Both placer and quartz claims have been located and will probably become ore producers as development proceeds. Now that access to the region has been made possible by the road, it is to be expected that during the coming season many prospectors will avail themselves of the opportunity to visit it and give it a thorough test. This field is not described in detail, because its mineralized belt, like that lying inland from the head of Portland Canal, appears to be entirely on the Canadian side of the boundary.

## SKAGWAY DISTRICT.

### PORCUPINE CREEK.

Placer operations on Porcupine Creek were begun early in the spring and successfully continued until the latter part of June, when an excess of water in the creek destroyed the large dam, filled the pit, and buried the sluice boxes and portions of the plant under many feet of gravel. A rebuilding of the dam and the removal of the débris was immediately begun, and at the end of the season it was reported that mining was again under way.

Hydraulic operations were continued on a small scale on both Nugget Creek and Salmon River, though no important progress was made.

### LITUYA BAY.

In this bay and along the coast for a few miles to the northwest the beach gravels have been successfully worked in a crude way since 1890 and considerable gold realized from them. During late years many locations have been made and companies formed to work these deposits, but their attempts have apparently not been successful.

## WRANGELL DISTRICT.

During the year 1905 no gold was produced in the Wrangell district. Several of the prospects show good surface indications, but have not been developed to any extent. As a whole the district has not yet been prospected thoroughly enough to permit an opinion on its mineral deposits.

## SITKA DISTRICT.

Mining in the Sitka district, as in the preceding one, has been unusually quiet the last year. Assessment work only has been done and no metal has been produced.

Low-grade gold- and silver-bearing quartz is the principal ore of the district and has been found near Sitka, in the vicinity of Silver Bay, at the Cache, Silver Bay, Lucky Chance, and other mines and prospects. The discovery of auriferous quartz veins near Cape Edwards, on Chichagof Island, was made during the summer of 1905, and developments are in progress at this point.

At Conclusion Point, on the southeast side of Baranof Island, several prospects have been located which are reported to give good assay values.

## COPPER.

In the deposits of copper the high-grade enrichment zone, which plays such an important role in the western mining camps, is practically absent, probably having been removed by erosion during the recent glacial period. As a consequence the belt of weathering and oxidation extends only a short distance below the surface and the ores are chiefly unaltered, unenriched sulphides. Leaching near the surface is not pronounced, and experience has shown that the values obtained a short distance below the surface approximate those at greater depths. A possible exception to this statement is at Copper Mountain, where surficial copper carbonates form the pay ore.

The copper deposits occur almost without exception as irregular lenses and masses, either as replacement or contact deposits or as heavily impregnated portions of schists. Their irregularity is so pronounced that in their exploitation the rule to observe is to follow the ore and not to drive long crosscut tunnels expecting to undercut the deposit in depth. The chief copper ore is chalcopyrite and cupriferous pyrite, accompanied by magnetite, pyrrhotite, and various other minerals. On Kasaan Peninsula the deposits may be described as bodies of magnetite and chalcopyrite averaging about 40 per cent metallic iron and containing 0.7 to 10 per cent metallic copper. A magnetic or mechanical separation of this ore has not been found practicable and it is shipped directly from mine to smelter.

### KETCHIKAN DISTRICT.

The principal copper deposits of southeastern Alaska are located on Prince of Wales Island, in the Ketchikan district. (See map, Pl. XI.) The conditions of their occurrence vary with the deposit, though in a general way they are similar. This is especially true of the copper bodies on Kasaan Peninsula and Tolstoi Bay. The geologic relations at Skowl Arm, Niblack, and Copper Mountain are noticeably different and will be discussed separately.

#### KASAAN PENINSULA.

Kasaan Peninsula is on the east side of Prince of Wales Island and extends in a southeasterly direction as a promontory 12 miles long and several miles wide into Clarence Strait. Its hills range from 500 to 3,000 feet in elevation, and are made up essentially of eruptive rocks, with occasional areas of sedimentary strata, all of which have suffered intense metamorphism. The bedded rocks include Paleozoic limestones and chloritic greenstone schists, intricately folded and faulted and cut by intrusive masses and dikes of diorite, diabase, andesite, and felsite. The ore bodies occur as flat-lying lenses, either in conjunction with magnetite, limestone, and felsite masses, or with garnet, epidote, and crystalline limestone in the contact aureole of intrusive granite-diorite bosses. The formation of both types of deposits is thought to be due primarily to pneumatolitic emanations from the intrusives, influenced perhaps by underground waters. In the special descriptions below only the salient features of each deposit will be emphasized, the details being left for the more complete report.

The Mamie mine, located on one of a group of claims owned by the Brown Alaska Company, is situated 1½ miles from Hadley. Considerable advance has been made during the last year at this mine. Diamond drills have been used in exploratory work and are said to have given encouraging results. In tunnel No. 2 a shaft 100 feet deep has been sunk and many drifts and crosscuts extended. The ore bodies belong to the low-grade chalcopyrite-magnetite type and contain besides these minerals pyrite, epidote, hornblende, chlorite, calcite, and quartz. They occur as flat-lying lenticular masses 100 to 200 feet long, incased in bands of limestone and various types of greenstone, and are cut by dikes of felsite, andesite, and uralitic diabase, locally known as diorite. The intimate association of the chalcopyrite, which is in general younger than the magnetite, with altered limestone, garnet, epidote, and hornblende, as well as its mode of occurrence, indicates its deposition from hot solutions, probably pneumatolitic, which were given off by the intrusive igneous rocks and which replace to some extent the invaded marble. Faulting is of frequent occurrence in the rock complex and has often cut off the ore bodies. The strongest system of fissure planes strikes about north and south and parallels the trend of the ore bodies, which pitch at low angles to the south.

At Hadley a 500-ton smelter has been erected with the necessary adjunct building, ore bins, and wharf. At the time of visit about 12,000 tons of ore had been delivered for treatment, and early in December the smelter was reported to have been started.

The Stevenstown group of claims is located on the crest of the hill above the Mamie mine and has been under active exploitation during the last summer. The ore body is a low-grade, flat-lying lens of chalcopyrite and magnetite, the upper covering of which has been removed by erosion so that at present it appears as a blanket capping the hill. Development consists of two tunnels and upraises, several test pits, open cuts, and surface strippings. The ore body has been found to be 20 feet thick at several points and often contains excellent showings of massive chalcopyrite. At several points surface oxidation of the metallic sulphides has developed a thin crust of limonite in which occasional flakes of secondary native copper can be observed. The ore body is cut by numerous dikes of porphyrite and uralitic diabase, which tend to increase the difficulties of estimating the amount of ore in sight. Limestone with epidote and other contact minerals was observed limiting the ore body on the east and also underlying it in places. A tramway has been extended from this property to the Mamie mine and serves to convey the ore to the smelter.

The Mount Andrew group adjoins the Stevenstown workings and lies in the same general mineral belt. Four ore bodies have been discovered and are flat-lying magnetite masses impregnated with some copper and small values in gold. The country rock is limestone, with various types of greenstone and felsite, and is in every way comparable to that at the adjacent Stevenstown and Mamie properties. The chief development work on this property was accomplished several years ago and consists of two long tunnels with several upraises to the surface, also test pits and open cuts. Although no work was in progress at the time of visit, a company is reported to have bonded the property recently and to have begun active operations.

Hole in the Wall is a small bight on the north side of the harbor at Hadley. The mountain to the north of its abrupt shore has been prospected for copper ore and several small chalcopyrite bodies with favorable showings discovered. They are contact deposits between greenstone and crystalline limestone, the associated minerals being garnet and epidote.

The properties of the Grindall Mining and Smelting Company are located about 3 miles southeast of Kasaan, and although they embrace a number of claims the actual development has been slight and confined chiefly to the Peacock and Tacoma claims. The ore bodies are contact deposits, accompanied by a gangue of garnet and epidote. They are irregular in shape, sporadic in occurrence, and intersected in many directions by later intrusive dikes both of felsite and diabase and by a system of fault planes. Chalcopyrite is the principal ore and is associated with magnetite and small amounts of molybdenite.

On the Peacock claim the developments consist of two short prospect tunnels not far from the shore, while on the adjoining claim several short tunnels and open cuts have been excavated. At the time of visit considerable ore had been taken from a deposit at tide water and placed ready for shipment.

The Uncle Sam group, originally called the White Eagle group, has received its present name by recent locators who have shown great activity in exploratory work. A gravity tram connects the mine workings at 500 feet elevation with a dock at tide water and furnishes economical transportation facilities. The ore bodies are irregular in shape and of the chalcopyrite-magnetite type. They contain low gold values and have been exposed by two tunnels and a short shaft, besides several open cuts and surface strippings. The main body averages nearly 6 feet in width and pitches apparently 45° N. It has been cut off by an east-west fault plane dipping 80° N. Above the lower tunnel an open cut and shaft follow a similar mass, which is probably part of the same lens. Associated with the chalcopyrite ore are pyrite, garnet, epidote, chlorite, and calcite, and these are noteworthy because of their probable origin in a contact aureole of limestone and eruptive rocks. The eruptive rocks show intimate connection with the ore bodies and consist of altered diorite and dikes of felsite and diabase. As a rule the chalcopyrite occurs sporadically with the result that the average metal content is low and requires skillful treatment to obtain satisfactory results.

The Copper Queen mine lies to the east of Kasaan and includes seven patented claims. The ore bodies occur ordinarily in a garnet-epidote limestone rock and have been exploited by several tunnels and test pits. Dikes of porphyry were frequently observed near the ore body, and along their contact slipping has taken place. Bands of greenstone were also noted intercalated in the beds of limestone. The chalcopyrite ore is accompanied by pyrite, magnetite, chlorite, garnet, calcite, and epidote. The ore bodies are irregular in shape and give low assay returns in copper and gold. Of late years litigation has suspended development work on the property.

The Poor Man's group of two claims is situated about 1½ miles from Kasaan and is reached from tide water by a tram one-half mile in length. The ore bodies are of the usual Kasaan magnetite-chalcopyrite type and have been exploited by a shaft 84 feet deep and several tunnels. Although the magnetite body itself is extensive the copper-pyrite masses occur only in isolated pockets, and are not disseminated throughout the magnetite sufficiently to make pay ore of the whole. Faulting is not uncommon and has caused minor displacements in the ore body.

### KASAAN BAY.

The Sunny Day group of three claims is located on the south side of Kasaan Bay, opposite Kasaan village. The vein follows the hanging wall of a wide porphyry dike striking N. 65° E., with vertical dip, and carries chalcopyrite with low gold and silver values. It has been traced for some distance by means of surface exposures and open trenches and found to vary not only in width but also in mineralization. The porphyry dike invades a complex of highly metamorphosed greenstones with occasional marble bands and bosses of diorite. A tunnel situated several hundred paces from the shore has been driven 135 feet to undercut the vein and should reach ore within the next 10 to 20 feet.

The Roman and Rosalie claims are situated at about 1,000 feet elevation above tide on the east side of Twelvemile Arm, near a small bay 2½ miles from Hollis. The ore consist , essentially, of pyrite and chalcopyrite with low values in gold and silver and is confined to a 6-foot band of marble, which forms part of an actinolite and chlorite-schist complex with some greenstone and indurated slate. A seam of soft gouge marks the foot wall and indicates movement along the bedding plane. Developments consist chiefly of a drift 40 feet long and a winze 25 feet deep.

### KARTA BAY.

Mining operations have been carried on at two points in the vicinity of Karta Bay during the last summer—namely, the Rush & Brown property and the Mammoth group. The ore bodies at both places are of the Kasaan type, and are to all intents magnetite masses enriched by chalcopyrite blebs and patches more or less irregularly disseminated throughout the whole. Their average content is so low that at present only the richer portions are mined. A magnetic survey of the Rush & Brown property has been made and the magnetite belt traced for a considerable distance. The mine workings are located in that portion of the belt which shows the maximum magnetic attraction and have given promising results. Since the copper-bearing bodies on Kasaan Peninsula ordinarily consist largely of magnetite, the advisability of locating and prospecting for them by means of the magnetic dip needle and dial compass or transit is apparent and to be recommended.

The Rush & Brown group of claims is located south of the first salt chuck or lake above Karta Bay. The developments consist of two shafts 26 and 100 feet deep, two short tunnels, and an adequate tramway and surface equipment. A railway 2 miles long, which is to connect a gravity tram from the mine with a deep-water dock in Karta Bay, is in course of construction and will reduce transportation expenses materially. The ore body has been followed for 100 feet in depth and good ore extracted most of the way. Its extent and size, however, have not yet been determined accurately.

Fault planes in the ore body were observed both on the surface and on the 100-foot level and limited the ore body at one point. At the time of visit a total of 1,300 tons of ore had been shipped and considerable ore was in the bins awaiting transportation.

The Mammoth group of claims is located on the north side of Karta Bay on the top of a low hill 500 feet in elevation. A good trail leads from the shore to the workings, which consist of a short tunnel and several open pits and crosscuts. The ore body is composed of magnetite and garnet with variable amounts of chalcopyrite and pyrite, and is usually low in values. The abundance of epidote, garnet, and calcite, together with the occurrence of limestone bands and greenstone in the immediate vicinity, indicates that the ore body has been deposited in a contact belt of limestone and probably by the pneumatolitic solutions emanating from the intrusive igneous rock. In position the ore body apparently caps the hill, and, like the Stevenstown deposit, it probably owes its peculiar form to resistance to erosion by glaciers. The occurrence of glacial débris, mud, and erratic bowlders, as well as deep glacial grooves, is evidence of the ice action at this place. The softer limestone has apparently been scoured off and only the tough magnetite mass left. There is good reason to believe that other deposits of similar type may be found underground in this vicinity.

### SKOWL ARM.

The Kiam mine is located near the head of McKenzie Arm, an inlet adjoining Skowl Arm, and has been greatly improved in surface equipment during the last summer. A gravity tram 2 miles in length connecting with an aerial tram 4,000 feet in length has been installed and suitable buildings and dock erected to insure economic handling of the ore.

The mine is situated in a wide belt of various schistose and gneissoid rock types, striking about east and west, with a dip of 65°–75° N., and invaded by a number of diabase dikes, which trend approximately with the formation and can be traced for several miles in that direction. The formation is banded and consists largely of quartz-sericite schists, interbedded in chloritic and actinolitic schists. Faulting has taken place on a large scale, and at least three different sets of fracture systems can be defined in the mine tunnel in conjunction with the ore body. They are also plainly marked in surface exposures, where they can be traced to better advantage and the actual displacement measured.

The ore bodies which have been developed are mineralized portions of certain bands in the formation which contain enough chalcopyrite to make them commercially valuable. The copper values are not uniformly distributed and the ore bodies are irregular in shape and size.

Pyrite, pyrrhotite, and chalcopyrite are the principle sulphides in the ore. Magnetite occurs in small quantities and also copper as a surficial alternation product of chalcopyrite. The gangue minerals are quartz, calcite, epidote, and chlorite. The ore is a low-grade smelting ore and requires economic handling and development to give good returns. Mine developments consist of two tunnels—a lower one 700 feet long, which was driven to undercut the ore body, but was finally abandoned without accomplishing its end, and an upper one, in which 260 feet of drifting and crosscutting had been accomplished at the time of visit.

The Mammoth and Lake View groups adjoin the Kiam claims on the east and are located on the eastern extension of the schist belt. Their ore bodies resemble the Kiam deposits so closely in character and occurrence that the above description may be applied directly to them. Zinc blende was noted among the sulphides, also intrusive diorite dikes, crosscutting the formation at small angles.

Several tunnels and open cuts have been driven to expose the ore and present favorable though small showings at several points.

### CHOLMONDELEY SOUND.

The prospects which have been discovered in the vicinity of Cholmondeley Sound are at present in an inert condition. Although developed more or less vigorously in former years, the Roundtree property, Friendship group, Lady of the Lake group, Gladstone, and other claims have received so little attention of late that they need not be considered here. Copper ore has been found in Cholmondeley Sound at the Argosy claim, on the south side of West Arm, and at the Fowlkes group, on Miller Creek, a tributary to the sound, about 2½ miles from Chomly post-office. At the latter claim chalcopyrite ore occurs as a mineralized band 12 eet wide in a gneiss-schist belt which strikes east and west and dips 60° N. A crosscut tunnel 95 feet long has been driven and the foot wall of the ore body reached. The surface exposures are well marked and often show surficial alternation products of the sulphide ore. The assay values are reported to be of sufficient grade to encourage further development.

### NIBLACK ANCHORAGE.

The Niblack Copper Company's mine has produced more copper the last year than any other camp in the district. It occupies a favorable position at the head of Niblack Anchorage in Moira Sound, and with adequate surface equipment should be able to extract ore at low cost.

The ore bodies occur as mineralized portions of schist bands in a complex consisting chiefly of greenstone schists with occasional belts of quartz-sericite schist and allied rock types. The formation strikes N. 60° W., with a dip of 60°-70° SW., and is cut by several later diabase dikes. Folding and faulting frequently occur and have an important bearing on the extent and shape of the ore bodies. Detailed work on these structural features in the mine has shown that the irregular outline of the ore bodies is often the result of intersecting fault planes. The largest ore body which has been discovered and from which most of the ore has been derived has been thus cut off by a fault plane crossing the formation at an acute angle. The ore body is about 80 feet long, 18 feet wide, and 20 feet high, with a pitch of 45° NE. The ore is essentially low-grade chalcopyrite, with small values in gold and silver. Pyrite occurs in great abundance and renders the ore suitable only for smelter treatment. Small veinlets of nearly pure chalcopyrite are associated with ferruginous quartz and constitute then the jasper ore of the miners.

The developments at the mine consist of a shaft 180 feet deep and over 750 feet of drifts and crosscuts, a rock house, hoist, wharf, and necessary mine buildings and surface improvements.

The Wakefield group of claims lies about 2 miles northwest of Niblack, at an elevation of about 1,000 feet, and can be reached by trail either from Niblack or the north shore of Moira Sound. The claims were located in 1904 and have not yet been thoroughly exploited. A shaft 50 feet deep has been sunk and a short drift tunnel extended at that level on one of the claims. The ore is similar in every respect to that at Niblack and occurs under like conditions in the general formation of schists and argillites. The mineralized schist band is wide enough to warrant considerable development if the values prove sufficiently high to pay. The ore is a low-grade chalcopyrite-pyrite ore with small values in gold and silver.

The property has recently been bonded by a large company, which plans to give it a thorough test the coming season.

### HETTA INLET.

The mining interests on the west coast of Prince of Wales Island are confined to a small area in the vicinity of Copper Mountain to the east of Hetta Inlet and extending for several miles inland. To present the geologic relations encountered and to show the mine positions the accompanying sketch map has been prepared (fig. 1). In the central portion of the area a wide intrusive stock or boss of granite invades irregular masses of limestone and quartzite of uncertain age. The masses of limestone have been so completely metamorphosed to coarsely crystalline marble that bedding planes are destroyd. The quartzites, which have a schistose and wrinkled structure, overlie the limestones and are in turn overlain by a wide belt of greenstone schist, which borders the shore of Hetta Inlet.

The general structure of the area strikes N. 15° to 30° W. and dips to the west, though this has been interrupted in the vicinity of the intrusive granite boss, where the stratified rock beds are usually parallel to its contact. These sedimentaries are provisionally referred to the Paleozoic.

The principal ore bodies in Hetta Inlet are on the Copper Mountain, Jumbo, and Green Monster groups and are confined to the contact areas of the diorite with either limestone or quartzite. The Corbin and Copper City deposits are of a different type, for they occur in the greenstone schists along the shore of Hetta Inlet.

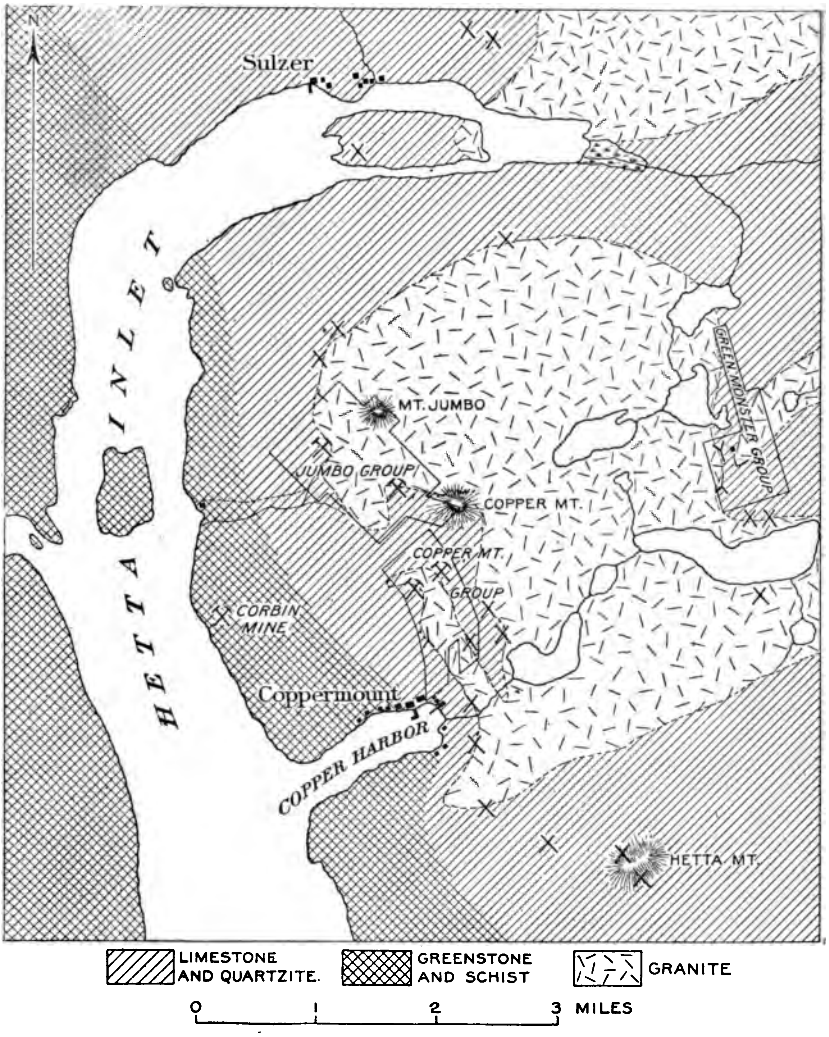

FIG. 1.—Geologic sketch map of Copper Mountain region.

The property of the Alaska Copper Company extends from tide water at Copper Harbor to the crest of the ridge west of Copper Mountain. The principal workings are on the New York and Indiana claims, three-fourths of a mile from the shore, 3,200 to 3,500 feet above sea level. At the New York claim the ore body is a band of garnet-epidote rock following the western contact of a granite belt about 700 feet in width and parallel to the main intrusive stock to the east. The mineralized band is irregular in shape and has an average width of 30 feet, though at the surface workings the width appears much greater on account of a spreading of the copper ores into the limestone hanging wall. This spreading has been accomplished by surface waters, which have leached the copper from the sulphides in the garnet gangue and redeposited it in the form of the hydrated carbonate (malachite, azurite) in the cavities and cracks of the shattered limestone hanging wall. Pockets of nearly pure malachite a few feet in diameter and of a columnar shape are often met with in these surface workings, though they have not been found in depth. At 2,300 feet elevation, or 1,000 feet below the surface outcrops, a tunnel has been driven 2,400 feet in length essentially in the granite-epidote rock along the granite-limestone contact. At the head of the tunnel drifts have been started both in the diorite and limestone in search of ore bodies richer than those at the contact, but have not yet proved successful. One of these crosscuts has penetrated the diorite belt for a distance of 600 feet in the direction of the Indiana claim.

At the Indiana claim much work was in progress and a wide body of low-grade ore was being developed by surface mining and tunnels. The mineral deposit is similar to that of the New York and follows the east side of the granite belt with limestone. It has been opened for several hundred feet in length and on the crest of the hill has a width of about 150 feet. Sulphide ores of iron and copper, with small amounts of the carbonate, constitute the ore and are disseminated throughout a garnet, epidote, and calcite gangue.

The Jumbo group of claims, the principal holdings of the Alaska Industrial Company, occupy the valley of Jumbo Creek on the north slope of Copper Mountain (fig. 1). The principal developments are on Jumbo claims Nos. 1, 2, and 4. On Jumbo No. 1 claim an extensive body of magnetite-chalcopyrite ore underlain by granite has been exposed by erosion over an area several hundred feet in width. Below these outcrops tunnels have been driven through the limestone hanging wall at various elevations to the foot-wall granite. In the garnet-epidote contact rock, which averages 50 feet in width, the magnetite-chalcopyrite ore is distributed in large scattered bodies with masses of barren rock intervening.

The Jumbo No. 4 claim, on the southeast slope of Jumbo basin, is located on a lode of garnet-epidote rock which strikes in a southeast direction away from the limestone-granite contact into the limestone country rock. The lode can be traced up the mountain slope for a distance of nearly 1,000 feet. It varies from 10 to 25 feet in width and often includes masses of crystalline limestone. Three tunnels at points 1,700, 1,800, and 1,850 feet in elevation have been driven into the lode, and in these the ore is irregularly distributed in masses carrying a high percentage of copper. The erection of an aerial tramway 8,000 feet in length, extending from this claim to Hetta Inlet, has been started and during the coming year large shipments of the ore will probably be made.

The Green Monster group of claims lies 5 miles by trail south of the head of Hetta Inlet, at an altitude of 2,200 to 2,800 feet. At present their position is not accessible for mining, and even to prospect them is costly and can be done only during the summer months.

The mineral occurrence is like that on the Jumbo group and follows the contact of granite and limestone. The contact zone is irregular and the metal sulphides are found in small masses or pockets in the garnet-epidote gangue rock. At the Diamond B claim a 65-foot tunnel follows this contact and exposes the garnet-epidote vein with small masses of ore along the first 50 feet, beyond which it enters crystalline limestone. On Green Monster No. 2 claim a vein, composed essentially of epidote, has been opened, which at first sight resembles a dike cutting the limestone. It is exposed for 200 feet in length, averages 6 feet in width, and has a S. 20° E. strike and vertical dip. In the tunnel, which is 65 feet long, copper ore was observed only in small amounts, though along the surface several pockets of both the sulphide and carbonate copper ores are exposed.

The Corbin mine is close to tide water on the east side of Hetta Inlet, 3 miles north of Copper Harbor. The mineral deposit is a narrow vein of massive sulphide ore, carrying a few per cent of copper and small values in gold and silver. It follows the general structure of the greenstone-schist country rock, striking N. 10° W. and dipping SW. 70°. The walls adjacent to the vein have been altered to a talc schist of light-green color and in places slipping grooves are prominent, pitching 50° NW. At the end of a 45-foot tunnel, which opens the ore body to the south, the vein narrows to a mere seam. From all indications the deposit appears to be an ore shoot, 5 to 100 feet in length and 1 to 3 feet in width, pitching to the northwest.

The Copper City mine, located as the Red Wing claim, lies on the east side of Hetta Inlet, 8 miles south of Copper Harbor. The ore body is a narrow vein of massive sulphide ore similar to the Corbin vein, though the percentage of copper contained is higher. The country rock is an altered greenstone schist interstratified with siliceous slate. It strikes north and south and dips 40° E. The vein parallels the bed-rock structure, has an average width of 2½ feet, and is composed of pyrite, chalcopyrite, and pyrrhotite, with some magnetite and small amounts of carbonate ore near the surface. Diabase dikes crosscut the ore body at various points and in places have caused faulting; they are usually a few feet wide and are later than the deposit. Developments consist of a 100-foot incline shaft and 200 feet of drifting and tunneling. A total of 1,600 tons of ore is reported to have been mined and shipped to the Tacoma smelter, yielding about $60,000 in copper and gold values.

### GRAVINA ISLAND.

On the south side of this island near Seal Bay and on Dall Head, copper-bearing ore bodies have been discovered which give some promise of value. In the past the properties have been operated only in a desultory way, so that at present it is not possible to form a definite idea of the extent and value of their deposits. They are low grade in character, irregular in shape, and occur in various kinds of rocks.

The Victor Mining Company, whose property is located near Seal Bay, has recently renewed operations and plans to continue them throughout the winter.

### WRANGELL DISTRICT.

At the head of Duncan Canal some exploration work has been accomplished on several low-grade copper-bearing ore bodies occurring in greenstone, but no concentrated effort has been made to develop any one prospect sufficiently to determine its value. The ore production has been very small.

## SILVER, LEAD, AND ZINC.

Up to the present time but few workable deposits of silver, lead, or zinc have been found in southeastern Alaska, and these are confined practically to the Wrangell and Ketchikan districts.

### WRANGELL DISTRICT.

In the Wrangell district the most important finds have been made on the mainland east of Wrangell, at Glacier and Groundhog basins. (See map, Pl. XI.) At both points the veins are inclosed in a belt of argillite, which lies between the Coast Range granite and the parallel outlying intrusive belt, as indicated on the sketch map. The veins are closely associated with light-colored porphyry dikes which have intruded the formation along its bedding planes. They consist largely of sulphide ores of lead, zinc, and iron, and vary in size from small stringers to strong veins 6 to 8 feet in width. During the past year assessment work only was accomplished on these properties. Several samples have been assayed and favorable returns reported.

### KETCHIKAN DISTRICT.

In the Ketchikan district two deposits of silver-lead-zinc ores have been discovered on Prince of Wales Island and may prove of future value.

The Hope group of three claims is located near the head of South Arm, Cholmondeley Sound, and is reached from salt water by a good trail 2 miles long. The deposits occur as bedding replacement veins 1 foot to 10 feet wide in crystalline limestone and strike about

N. 65° E., with variable dip. A reverse in dip from 30° NW. to 50° SE. was noted between the vein at the lower (elevation 2,190 feet) and the upper workings (elevation 2,300 feet) and was attributed to a large synclinal fold in the limestone. The deposits have been opened by an inclined shaft 20 feet deep and by numerous open cuts. The metallic minerals are chiefly zinc blende and galena, with low values in silver. Cerussite was observed as an alteration product.

Several other claims have been located above this property on similar veins, but have not been developed to any extent.

The Oregon and Idaho claims are situated between Dora and Mineral lakes, near Cholmondeley Sound, and are located on a well-defined vein which averages perhaps 3 feet in width and is exposed for over 300 feet. The country rock comprises several types of schists, often chloritic and folded, and striking usually about north and south with a steep dip to the southwest. Good values in silver, gold, and zinc have been obtained from the ore.

# NONMETALLIC DEPOSITS OF SOUTHEASTERN ALASKA.

By C. W. Wright.

## INTRODUCTION.

In southeastern Alaska, as in all new mining regions, prospecting has favored the metallic and neglected the nonmetallic deposits. The commercial value of large bodies of gypsum, marble, granite, and cement materials, all of which are in great demand for building purposes, is rarely known to the average miner, and only during recent years has the presence of such deposits in this region been recognized. Developments on certain properties have already reached the producing stage, and it is probable that in 1906 large shipments of both marble and gypsum will be made.

Coal has been discovered at several localities, principally on Admiralty and Kupreanof islands, and attempts have been made to find workable seams, but with little success.

Mineral water in commercial quantities has been discovered at several places and is being placed on the local market.

## MARBLE.

Areas of limestone metamorphosed to marble are of frequent occurrence on the many islands and along the mainland of southeastern Alaska. (See map, Pl. XI.) Marble deposits of commercial importance, however, are relatively few. Those at present under development are in the proximity of granite masses and have resulted from the metamorphic action of the intrusion. The principal factors affecting the value of marble deposits are extent, position relative to transportation and market, absence of fractures or joints, facility of extraction, fineness of grain, color, and lack of objectionable impurities, such as vein pyrite, bitumen, etc. The most valuable marble found in this field has a fine granular texture and pure white color.

The market for this stone will be in the cities along the Pacific coast, and it will therefore compete with the marble quarried in the three most western States. The following table shows the production of the west-coast marble in 1904, with the average value at quarries per cubic foot:

*Production and value of marble in 1904 for California, Washington, and Oregon.*[a]

| | Sold rough, for— | | | Sold dressed, for— | | |
|---|---|---|---|---|---|---|
| | Building. | Monumental. | Other purposes. | Building. | Monumental. | Interior decoration. |
| Total production | $9,810.00 | $9,073.00 | $1,100.00 | $11,800.00 | $7,854.00 | $71,120.00 |
| Average value at quarry per cubic foot | 1.10 | 2.25 | | 1.60 | 3.20 | 5.00 |

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[a] Compiled from Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905, p. 833.

### PRINCE OF WALES ISLAND.

Three mining companies—the Alaska Marble Company, the El Capitan Marble Company, and the American Coral Marble Company—are developing extensive marble deposits on this island.

The properties of the Alaska Marble Company are at the north end of the island and extend 4 miles north from Shakan village. They lie in a wide marble belt, probably of Devonian age, near the contact of a granite mass which forms the low mountains to the east. Dikes of diabase, though rare, were noted intersecting the marble. Both fractures and joints are present in the marble exposures, though in the quarry extending 20 feet below the surface these are less frequent and will not interfere materially with quarrying. The deposit has been thoroughly tested at various points by 18 drill holes, sunk to depths of 20 to 80 feet, from many of which a marble of excellent quality was obtained. The marble is of a moderately fine granular texture and in color varies from bluish to pure white. Analysis shows 99.26 per cent of calcium carbonate and 0.3 per cent of magnesia. No injurious impurities are present and the material is readily quarried.

The principal workings are at an altitude of 100 feet above sea level, on the south side of Marble Creek, 3,200 feet from the end of a wharf at deep water. An area 100 by 200 feet has been stripped of vegetation and a cut with a 20-foot face has been excavated. Derricks and marble-cutting machinery have been installed and were in operation preparatory to the making of a large shipment. Blocks 6 by 6 by 4 feet and approximately 11 tons in weight are to be quarried and shipped to Puget Sound, where the marble will be prepared for the market.

The El Capitan Marble Company began operations early in 1904 on a group of claims located on a cove on the north side of Klawak Passage, 6 miles from Shakan village. The marble deposit borders the east contact of a granite mass represented on the geologic map (Pl. XI), and from its relative position and similarity to the deposit of the Alaska Marble Company can be correlated with it.

At the quarry, situated close to the water, many joints and fractures were present in the surface stone, though from the pit 15 feet below the surface large flawless blocks had been extracted. The marble has a moderately fine granular texture, is of a bluish-white color, and is easily quarried.

During 1904 a marble-sawing plant was erected, channeling and gadding machines were installed, and 15 tons of marble were mined. This product was cut into slabs from 1 to 4 inches thick and 4 to 6 feet wide and shipped to Seattle to be polished and prepared for market. Proper transportation facilities are lacking, and before large shipments can be profitably made a wharf must be built and more extensive excavations made.

The American Coral Marble Company owns a group of claims near the head of North Arm, a narrow inlet on the east coast of Prince of Wales Island. The surrounding rock beds are largely of banded marble interstratified with chlorite and serpentine schists, all of which strike N. 65° W. and dip 85° SW. A few miles to the northwest a granite mass intrudes these beds. The limits of the deposit have not been determined and where exposed, in the open cuts and short tunnel driven on the property, the marble was much fractured and variable in color.

The joints or fracture planes were probably formed during the period of tilting or folding of the beds and existed before erosion exposed the present surface outcrops. Since that time weathering has accentuated and to some extent increased in number the fracture planes, and it seems probable that in depth these may, although potentially present as lines of weakness, become less frequent and not interfere greatly in quarrying.

While some parts of the deposit consisted of a pure white, fine-grained marble of excellent quality other portions were poorly colored, coarse grained, and of little commercial value. The better grade gave the following analysis: Calcium carbonate, 94 per cent; alumina, 3.9 per cent; silica, 1.4 per cent; magnesia, 0.7 per cent. Pyrite in disseminated particles was observed in some of the marble.

During the last summer a wharf, connected with the quarry by a tramway, was completed, adequate buildings were erected, and much machinery installed. It is proposed to ship the product in large blocks to Puget Sound, there to be polished preparatory for the market.

At Dolomi, just north of the entrance to North Arm, this company has located a second group of claims on a marble belt. Its quality, however, is said to be inferior to the above-described deposit and has not encouraged extensive development.

#### REVILLAGIGEDO ISLAND.

A wide belt of marble exposed in cliffs near tide water was discovered last summer on the north side of George Inlet and was located as the Bawden group. The deposit lies in the schist-argillite belt adjacent to the Coast Range granite. It is made up of beds of massive marble 10 to 20 feet in width, separated by strata of calcareous schist striking northwest and dipping northeast. The marble exposed is of good quality and relatively free from fractures and joints. This deposit has not yet been developed.

The George Inlet marble belt extends in a southeasterly direction into Carroll Inlet. Here also locations have been made in previous years, but no developments have followed, and the value of the marble is not known.

#### HAM ISLAND.

Ham Island lies at the junction of Blake Channel and Bradfield Canal, 25 miles southeast of Wrangell. It is about a mile long and half a mile wide, and consists largely of massive marble with interstratified beds of calcareous schist striking N. 35° W. and dipping 75° NE. Intrusive dikes of basalt are common, while across the narrow channel on the mainland and on Wrangell Island wide belts of granite occur in the marble areas and have probably induced the present crystalline texture in the marble.

Two distinct varieties of marble are found—one fine grained and pure white, the other very coarse grained and of a pale-blue color. Several systems of jointing planes traverse the deposits, but the joints are widely separated and will not interfere greatly in quarrying. Checks or surface cracks are practically absent and wide areas of massive marble have been found directly underneath the soil. Much of the marble appears to be free from impurities.

The Woodbridge-Lowery group of claims lies on the west side of Ham Island and the Miller group on the east side. Considerable exploration work has been done by the owners of each group and some marble has been quarried for local use. The properties are favorably located both for quarrying and transportation.

### LIMESTONE.

Limestone is abundant among the sedimentary rocks of southeastern Alaska. Belts miles in width are exposed, and the rock can be quarried at a slight cost. The market value of this crude rock, however, at Seattle or San Francisco, is less than the present cost of transportation from Alaska to these cities and it is therefore of value only to local consumers.

### GRANITE.

Observations on the granite of southeastern Alaska have been confined to examination of natural exposures of the rock and of its appearance under the microscrope. No physical tests have been made to determine the strength and durability of the stone.

The main granite belt of the Coast Range varies from 40 to 80 miles in width and, though considerably sheared along its contact and interrupted by occasional narrow bands of schist, contains wide areas of massive rock which would apparently make excellent building stone. In addition to the Coast Range belt isolated stocks or masses of granite, often miles in width, form the backbone of many of the islands and border the mainland. The central portions of these granite masses are comparatively uniform in composition and size of grain, whereas near their contacts with the intruded rock beds they are often segregated into acidic and basic masses and cut by aplite and pegmatite dikes.

Several distinct though related granite types are found, in all of which plagioclase feldspar is an essential constituent. Hornblende is the usual dark mineral, though biotite mica is often present and in rare instances exceeds in amount the hornblende. Quartz is commonly present, though usually in small amounts. The accesssory components are apatite, titanite, and magnetite; secondary minerals, due to general metamorphism, are sericite, epidote, zoisite, chlorite, and calcite. Petrographically the rock is often related more closely to the diorites than to the true granites and is often referred to as a diorite.

The prevailing color of the granite is a light gray and only in rare instances were pink or reddish masses observed. The grains of the component minerals are ordinarily of medium size, not differing greatly in the different localities. Evidence of the durability of the granite is afforded in many places where long exposure to the influences of weathering has caused little or no disintegration of the surface.

Investigations of granite or other building stones have been meager in southeastern Alaska, principally because of a lack of knowledge of their value. In the large cities bordering the Pacific coast the increasing use of stone for building purposes has created a widespread and growing demand. The controlling factor in the successful operation of a quarry is often not the intrinsic value of the stone, but rather its market price and the position of the quarry relative to the market. The actual cost of stone depends on the ease of quarrying in blocks of the required form and the facility with which the stone can be dressed. Other factors, such as the color, durability, and susceptibility for taking a high polish, also govern its value. It is seldom that all the stone of a quarry is of uniform grade, and sorting it into classes is usually necessary. The large flawless blocks are of most value for monumental purposes. For building and construction works blocks of smaller size are used and the market value is considerably less. The smallest material and inferior grade of rock are often of value as paving stone or for road metal.

The following table shows the average value of granite and the production of 1904 in the three most western States, with which Alaska will probably enter into competition:

*Average value and production of granite in 1904 in California, Oregon, and Washington.*[a]

| | Sold rough, for— | | | Sold dressed, for— | | |
|---|---|---|---|---|---|---|
| | Building. | Monumental. | Other purposes. | Building. | Monumental. | Curbing. |
| Total production | $72,115.00 | $63,014.00 | $222,351.00 | $421,394.00 | $137,658.00 | $80,653.00 |
| Average value at quarry per cubic foot | .85 | .98 | ............ | 3.25 | 4.80 | [b].85 |

[a] Compiled from Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905. p. 814.
[b] Per linear foot.

The above values do not represent the market value of the stone laid down in the cities along the coast, as the cost of transportation from the quarries is not included. From most points in southeastern Alaska where granite occurs the facilities of loading the quarried stone directly into ocean-going vessels are exceptionally favorable and a freight rate of from $1 to $2 per ton can be obtained. Investigation of this as yet undeveloped resource of the region is to be recommended.

## GYPSUM.

The increasing use of gypsum as a building material, together with its importance as a wall plaster and fertilizer, makes it of increasing commercial importance.

The following table shows the value and production of this rock in the United States:

*Production of gypsum in United States, 1904.*[a]

| Grade. | Quantity (tons). | Value. | Average value per ton. |
|---|---|---|---|
| Crude | 56,137 | $61,234 | $1.09 |
| Land plaster | 70,167 | 142,490 | 2.03 |
| Plaster of Paris | 274,672 | 882,262 | 3.21 |
| Wall plaster | 390,668 | 1,698,339 | 4.35 |

[a] Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905, p. 1037.

These average values represent the prices at which the various classes of product were sold at the mines and plaster plants, respectively. It can readily be seen that only extensive deposits situated favorably as regards mining and transportation can be worked with profit. Gypsum in sufficient quantity to warrant extensive development and extraction is known to occur at only one locality in southeastern Alaska.

The Pacific Coast Gypsum Manufacturing Company owns claims on Gypsum Creek, at the head of Iyoukeen Cove, a small bay on the east shore of Chichagof Island. Here a small bluff of gypsum interbedded with cherty limestone was discovered 1 mile up the creek, and many tons of the rock have been quarried. Tests were made which proved this material to be an exceptionally pure gypsum and further investigations of the deposit have followed. Two tunnels 600 feet apart were driven on Gypsum No. 3 claim, and in each of these shafts 65 and 75 feet deep were sunk, almost entirely in gypsum. At the lower workings the gypsum bed appears to have an east-west strike and a dip of 60° S. Overlying it are strata of chert conglomerate, while beneath it beds of cherty limestone were exposed. From the bottom of the shaft the deposit is exposed by a crosscut for a width of 90 feet, entering to the north the hanging-wall conglomerate, but to the south penetrating a diabase dike. At the upper workings on the south side of the creek two beds of gypsum have been exposed in the shaft. These appear to lie relatively flat and are separated from each other by a stratum of conglomerate 17 feet thick. The upper bed is 40 feet thick, and at the time of the writer's visit the shaft entered the lower bed for a depth of 12 feet, but had not passed through it. The extent of the deposit was being investigated by drifts starting from the shaft and penetrating the beds in various directions.

The gypsum and conglomerate beds rest unconformably on Upper Carboniferous limestones and are probably of early Mesozoic age, as are many of the gypsum deposits in the Western States.

Developments on a large scale by this company are in progress, and a railroad 1 mile in length is in course of construction, which will transport the gypsum from the mine to bunkers of 1,000 tons capacity to be built on a wharf. The crude product will be loaded directly into hulks or barges and shipped to Puget Sound, where a plaster mill is to be built.

## COAL.

The most extensive explorations for coal in southeastern Alaska have been at Kootznahoo Inlet and Murder Cove, on Admiralty Island,[a] and Hamilton Bay, on Kupreanof Island. At these localities the coal-bearing formations are Tertiary in age and made up of conglomerate, sandstone, and shale. These beds are all more or less faulted and appear to occupy basins formed in the more ancient rock beds. The coal is with few exceptions an impure lignite and occurs in narrow seams of no commercial value.

At Murder Cove explorations were made on a seam 5 feet thick located 2 miles from deep water. This deposit, which contains the best grade of coal in the region, proved to be of very limited extent and not worthy of further development.

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[a] Wright, C. W., A reconnaissance of Admiralty Island: Bull. U. S. Geol. Survey No. 287, 1906 (in press).

## MINERAL SPRINGS.

Cold mineral springs have been found at St. John Harbor, on Zarembo Island, at several points near Eddystone Rock, in Behm Canal, and up Unuk River.

At Zarembo Springs the water contains considerable carbon dioxide with various mineral salts, which lend to it an agreeable flavor. The point of outflow, which is covered at high tide, has been incased and a small wharf built over it. The water forces itself up through a pipe, from which demijohns and barrels are filled and shipped to Seattle, where bottling works have been established.

In Behm Canal the principal spring is situated on the east side of Revillagigedo Island, opposite Eddystone Rock. The waters emerge from fracture cracks in a banded-schist complex cut by pegmatite dikes. The flow at this point is greater than at Zarembo Springs. Carbon dioxide and a small percentage of sulphureted hydrogen are present in the water, the latter giving it a disagreeable odor. Small shipments have been made from these springs for the local trade.

On the north bank of Unuk River, about 20 miles from the mouth and 2½ miles below the international boundary, a strongly carbonated spring flows from a fissure in the granite. Its temperature is 7° C. (44° F.) and the daily discharge about 1,000 gallons. With good transportation facilities this spring should prove valuable.

## THERMAL SPRINGS.

Thermal springs occur at several points in southeastern Alaska and have been found by experience to possess medicinal properties of great value to sufferers from rheumatism and other ills resulting from exposure. The Indians were the first to appreciate the healing power of the springs and made use of them long before the invasion of the whites. Of late years cabins and bath houses have been built at several of the springs for the accommodation of visitors. Southeastern Alaska, however, is not an ideal summer resort, owing to the excessive rain, and the springs can not be so valuable commercially as in more-favored districts.

The springs occur without exception within intrusive granite belts and issue from fracture planes in the same. In temperature they range from 65° C. (150° F.) to 95° C. (203° F.). They are extremely variable in composition and precipitate, on cooling, various minerals, forming crustified deposits. The rate of discharge is not the same for different springs and varies, probably, from several hundred to 1,500,000 gallons per day. One of the hottest springs is located near Bailey Bay, Behm Canal, in the Ketchikan district. The water at this point issues from a fissure in the granite in the form of a jet 15 inches high and 1 inch in diameter. On Bell Island, just west of Bailey Bay, and on the north side of Unuk River, 6 miles from its mouth, are similar hot springs, which are frequently visited. The spring with the greatest flow is situated opposite Great Glacier on Stikine River, above the international boundary and serves the inhabitants of the Wrangell district. In the Sitka district the principal hot springs are 15 miles south of Sitka, at Hot Springs, where good baths and houses have been built. Other localities where similar improvements have been made are Tenakee Inlet, on Chichagof Island, and Warm Spring and Cook bays, on Baranof Island. Definite analyses and temperatures of the various waters could not be obtained.

# THE YAKUTAT BAY REGION.[a]

By Ralph S. Tarr.

## GEOGRAPHY.

From Cross Sound to Controller Bay, a distance of over 300 miles, the coast line is remarkably straight and contrasts strikingly with the deeply indented coast to the southeast and northwest. (Pl. II.) Its straightness is due to the steeply rising mountain wall of the St. Elias Range and to a seaward fringe of glacial débris brought down from the mountains during a former period of greater extension of glaciers. At this earlier period glaciers spread out at the mountain base, as the Malaspina Glacier now spreads out at the base of Mount St. Elias. The moraines and deposits from these glaciers built the low foreland which fringes the mountain base.

About midway this straight stretch of coast line is broken by the broad Yakutat Bay, the only notable indentation in this part of the Alaskan coast. Yakutat Bay opens to the Pacific as a broad V-shaped bay about 20 miles wide at the entrance, shallow at the mouth and deepening toward the head. Its outer shores are low where it extends across the foreland, but they abruptly rise where the bay enters the mountains, and thence onward to its head the bay is a magnificent fiord. Where both shores of this bay enter the mountains it is called Disenchantment Bay. At the head of Disenchantment Bay the fiord abruptly turns and extends back toward the Pacific. This part is called Russell Fiord, and its head lies outside of the mountains in the foreland east of Yakutat Bay. There are two small branches of Russell Fiord, known as Nunatak Fiord and Seal Bay, respectively. The whole fiord resembles a bent arm with the shoulder at the Pacific, the fist at the head of Russell Fiord. On the inner side of this bend is a mountainous peninsula with peaks rising from 3,000 to 4,500 feet. The other shores rise to still greater heights, reaching 5,000 to 6,000 feet within a few miles of the fiord. Back of these peaks, toward the north, northwest, and northeast, snow-capped mountains rise to heights of 10,000 to 16,000 feet.

The low mountains of the peninsula support small valley galciers, but from the higher mountains huge ice streams descend, three of them reaching the sea. Of these glaciers the largest is the Hubbard, which discharges its icebergs into Disenchantment Bay, where they join the bergs from the smaller Turner Glacier, a few miles farther southwest. The third tidal glacier is the Nunatak, which enters the head of Nunatak Fiord. South of this is a large, nontidal glacier called the Hidden Glacier. There is clear evidence that these glaciers were once more extensive and, in fact, that they formerly extended throughout both arms of the fiord. For years most of the glaciers have been receding.

## STRATIGRAPHY.

Neither the fossils nor the rock collections have as yet been carefully studied, so that it is at present impossible to make a final statement of results. There are four terranes of distinctly different character, which for the present will be called, respectively, (1) the crystalline rocks, (2) the "Yakutat" series, (3) the coal-bearing beds, and (4) the unconsolidated deposits.

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[a] Acknowedgments are due to my two associates, Lawrence Martin and B. S. Butler, for efficient assistance in this work.

## CRYSTALLINE ROCKS.

The crystalline rocks, which are evidently the oldest, consist of a great variety of both igneous and metamorphic types. It includes granite and other plutonic igneous rocks, different kinds of gneisses and schists, slates, and stretched conglomerates. The crystalline rocks lie farther inland than the Yakutat series,[a] and the boundary between the two is a nearly straight line extending along the northwest arm of Russell Fiord, crossing Nunatak Fiord diagonally, and thence running across the mountains to Hidden Glacier, which occupies the next large valley south of Nunatak Fiord. Where the two series outcrop on the south shore of Nunatak Fiord and in the Hidden Glacier valley they are evidently separated by a fault; and an extension of this fault would carry it down the northwest arm of Russell Fiord. In consequence of this difference in formation, the northeastern shore of the northwest arm of Russell Fiord is bordered by slate and the southwestern shore by the Yakutat series. No fossils were found in the crystalline rocks to indicate their age, but the great amount of intrusive rock and the highly metamorphosed nature of the sedimentaries indicates a greater age than that of the neighboring Yakutat series.

## YAKUTAT SERIES.

Between the crystallines and the foreland, both on the peninsula and in the mountains to the northwest and southeast of it, there is a complexly folded and faulted series of rocks in which the three most prominent elements are (1) a series of thinly bedded black shales and gray sandstones, (2) a black-shale conglomerate, with crystalline pebbles and bowlders, and (3) a massive crystalline rock of peculiar nature and relations. In some places this last rock is sandy in character and in others conglomeratic, including angular fragments of black shale in bands. Under the microscope it appears to be fragmental and shows quartz, fresh feldspar, mica, and other minerals. For the present, awaiting further petrographic study, this rock is tentatively classed as an indurated tuff. It occurs in great masses and is the most prominent rock in the Yakutat series.

In addition to these rocks there are lesser areas of coarse conglomerates, occasional dikes, and limited areas of granite, crystalline limestone, and a dioritic rock. The field relation of the granite and other crystalline rocks indicates that these are the basement on which the true Yakutat series rests, with the black-shale conglomerate at the base of this series.

It was found impossible to work out the succession in the Yakutat series, or to make even an approximate estimate of its thickness. The entire series is complexly folded in great compressed, overturned folds and is complicated by an intricate series of minor folds, contortions, and faults. The folding and faulting has often resulted in a veritable kneading of the rock strata, and frequently in a brecciation. A score of faults are often visible on a single outcrop a few square yards in area. But this complex folding and faulting has not sufficed to metamorphose the strata.

The Yakutat series is remarkably unfossiliferous, not because of destruction of the fossils, but evidently because of their original absence from the beds. Plant fragments and some animal remains occur occasionally in the thin-bedded shale-sandstone strata, but a careful search failed to discover any beds yielding abundant or characteristic fossils. The report of T. W. Stanton indicates that the fossils are not sufficiently typical to determine the age of the series.

## COAL-BEARING BEDS.

Just outside of the mountain front, on the west side of the head of Yakutat Bay, occurs what is apparently a younger series than the Yakutat It consists of sandstones, clays, brown shales, and some coal beds. These beds dip steeply westward (45°-75°) and are markedly in contrast with the Yakutat series in general lithologic character, in degree of induration, and in the absence of marked folding and faulting, all of which indicate more recent age. Their exact relation to the Yakutat series could not be determined, the contact being hidden beneath glacial débris; but the two series were traced to within a quarter of a mile of each other. It is probable that they are separated by a fault.

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[a] The terms Yakutat, Rampart (p. 130), Orca (p. 80), and Valdez (p. 80) series were applied by the early explorers to large heterogeneous aggregations of rocks about which little was known. The names are still retained, although this use of the word "series" is not in accord with the rules of nomenclature given in the Twenty-fourth Annual Report. With more detailed work, these aggregates probably will be subdivided, and the word "series" abandoned.

In one layer abundant plant fossils were found. The collections from this layer have not been studied, but from a hasty examination F. H. Knowlton reports as follows:

> There are six or eight species of plants present, among them being minute fragments of a conifer, two ferns, and a number of dicotyledonous leaves. The conifer appears to be a *Glyptostrobus* or a very slender *Sequoia*. The ferns both belong to the genus *Dryopteris*, one of them being in beautiful fruit. This fern is hardly to be distinguished from a species now living in Jamaica. The dicotyledons seem very modern in appearance, among them being one beautifully preserved leaf which I am not able at the moment to distinguish from an undescribed species of *Sterculia* from Pliocene beds of the Cascades of Columbia River.
>
> So far as this hasty examination shows, none of the plants is referable to the Kenai, and if the exigencies of the stratigraphy demand that they should be referred to the Pliocene, there is nothing to contradict it.

## UNCONSOLIDATED DEPOSITS.

The unconsolidated beds include a complex series of glacial and aqueous deposits. Some of these are being laid down now in the form of moraines along the termini of the glaciers and as alluvial fans by glacial and other streams. Some of the deposits were formed during earlier advances of the ice. To the latter class belongs much of the deposit making the foreland and also a series of gravels forming cliffs and terraces at various points along the shores of Yakutat Bay and Russell Fiord. These terraces consist of cross-bedded sands and rounded gravels containing a large percentage of crystalline rocks. Scattered through these gravels is some gold, which, when concentrated by wave action on the beaches, forms deposits which are worked in a small way.

## ECONOMIC GEOLOGY.

Yakutat Bay has been a highway for a large number of prospectors on their way to the gold fields of the Alsek Valley. One route was over the Nunatak Glacier; another to the head of Russell Fiord, thence overland to a glacier leading back to the Alsek. Naturally, therefore, the shores of the fiord have been quite extensively prospected. As a result there has been much staking of claims, but no discoveries of important mineral deposits have so far been made. Four substances have been sought here—petroleum, coal, platinum, and gold. Each of these will be briefly considered.

### PETROLEUM.

Definite information concerning the reason for the search for petroleum could not be obtained. Probably the principal incentive was the discovery of petroleum farther northwest in a similar topographic situation; but it is reported that surface indications of oil have been seen, though the present study failed to find any of the localities. Whatever the reason, the shores of the bay were staked promiscuously, both on the glacial deposits of the foreland and the hard rocks of the mountains. No explorations were made so far as could be learned.

There seems little reason to suspect the presence of oil here. The glacial deposits of the foreland may of course cover oil-bearing beds, but nothing short of borings would demonstrate this. The rocks of the Yakutat series seem unpromising, both because of their barrenness of organic remains and their shattered condition, which would seem to be most unfavorable for the storage of oil. Altogether the prospect of finding petroleum here seems very slight. None of the Alaska oil wells are in rocks of this lithologic character or age.

## COAL.

Several small beds of lignitic coal occur in the coal series west of the head of Yakutat Bay, the largest being 2 to 3 feet thick. These beds outcrop along a small mountain stream bed and a mile or more farther west along the stream which issues from the Atrevida Glacier, and some prospecting has been done in each place. On the Atrevida outcrop a short tunnel, now caved in, was made by Jack Dalton. Although the coal is apparently of fair quality for lignite, the small size of the seams and their situation give little indication of future value in competition with the coals farther northwest. Even if the coal were better and the seam larger, the situation is adverse to development, for the coast nearest the mine is exposed to waves which enter the broad bay from the Pacific, and it is rendered more unfavorable by the almost constant presence of a stream of icebergs from the Hubbard and Turner glaciers. This band of floating ice is sometimes difficult to pass through.

Coal has been reported from the Yakutat series, but the writer was unable to discover any or to find anyone who knew definitely where any occurred. Very thin seams of coal were found in a few places in the black shales, and some bits were found in moraines. If coal occurs in these rocks, the folding and faulting would unquestionably introduce most serious problems for successful mining.

## PLATINUM.

The report of the presence of stream platinum has led to some search for this metal, and in 1899 a party of prospectors washed the gravels of an alluvial fan near Hubbard Glacier for platinum, but had no material success.

## GOLD.

Wherever the gravels of the beaches in the fiord were washed during this study colors were found, and prospectors report the same result, but state that it is rarely in paying quantities. It appears to be most abundant near the gravel terraces of earlier glacial origin. At two points the washing of the beach gravels is at present intermittently carried on in a small way. One of these is near Yakutat, on the ocean beach of Khantaak Island, where the waves are cutting back into a gravel cliff of glacial origin. The other is at Logan Beach, north of Knight Island, on the eastern side of Yakutat Bay, where the waves are also cutting into a gravel terrace formed during the greater advance of glaciers in this region.

In each place there seems to be considerable gold, especially where the high waves have been working at the base of the gravel cliff. The chief difficulty is the absence of sufficient water easy of access. Taking advantage of the run-off from rains, parties of two or three work these beach deposits now and then. One party of three was at work on Logan Beach at the time of the writer's visit and reported that they were barely making wages, but it had been a peculiarly unfavorable period of clear, dry weather.

It is possible that with more water successful gold washing could be done, and Logan Beach has an abundant supply available at a moderate expenditure. Up to the present time the gold washing has all been done by parties going out for a few days or weeks and employing the simplest possible devices for leading water to their rockers.

That the gold comes from the gravels admits of no doubt, and this naturally raises the question whether they too may not pay for washing on a large scale. On this point no information is at hand further than the fact that gold, probably in small quantities, exists in the gravels here and elsewhere on the shores of the fiord.

Attempts have been made by prospectors to find the source of this gold; but, so far as could be learned, by searching in the immediate neighborhood of the gravels themselves and particularly in the valleys back of the terraces, this search has naturally been fruitless, since the gravels were brought to their present position by streams supplied by the melting glaciers, formerly more extensive. The source of the gold is back in the crystalline rocks, and the search for it, if carried on, should be directed there. It may be so disseminated as to be of no economic value, or, if not, it may occur so far back among the glaciers as to be inaccessible; but there, and not among the rocks of the Yakutat series, it will be found, if anywhere.

# DISTRIBUTION AND CHARACTER OF THE BERING RIVER COAL.

By G. C. Martin.

## INTRODUCTION.

The following pages contain some of the more important facts of an economic bearing brought to light during last season's work in the Bering River coal field. Preliminary reports[a] based on earlier reconnaissance work have already been published. The work of the season of 1905 was of a detailed character, including not only careful geologic studies, but the preparation of detailed topographic and geologic maps. A final report, to be accompanied by these maps, is in preparation.

The mining developments of the past year have consisted almost entirely of prospecting, of land surveys, and of surveys for railroad connections with tide water. Several important tunnels are under construction, but at no point has work progressed far enough to permit the mining of coal in commercial quantities, even if transportation were provided. Local developments have been held back by the lack of shipping facilities and also by delays in securing title to the land.

## EXTENT OF THE FIELD.

The area of coal-bearing rocks is shown approximately on the accompanying map (fig. 2). While the southern limit of the field is known with considerable accuracy throughout its entire extent, the western boundary is uncertain, appearing to be in part determined by a zone of faulting. The coal disappears under the overlying rocks along the northern border of the field, where in some places it seems to be cut off by faults, but in other places presumably extends for a considerable distance under the overlying rocks and under Martin River Glacier. Whether or not the coal is here at such depths and under such conditions as would render mining feasible is not known. The eastern termination of the field is not known, as it extends beyond the region in which geologic field work has been done. The area of coal outcrops is at least 50 square miles. Probably at least 20 square miles more are underlain by coal at a greater or less distance below the surface.

## GEOLOGIC SECTIONS.

The general geologic sequence and the age of the rocks in the Controller Bay region are shown in the following table:

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[a] Petroleum fields of Alaska and the Bering River coal fields: Bull. U. S. Geol. Survey No. 225, 1904, pp. 365-382. The petroleum fields of Alaska, with an account of the Bering River coal deposits: Bull. U. S. Geol. Survey No. 250, 1905. Bering River coal field: Bull. U. S. Geol. Survey No. 259, 1905, pp. 140-150.

*Geologic formations in Controller Bay region.*

| Age. | Name of formation. | Lithologic character. | Thickness in feet. |
|---|---|---|---|
| Quaternary | | Silts, sands, and clays | |
| Tertiary | | Shale, with some sandstone | 2,000+ |
| Do | Kushtaka formation | Arkose, with coal beds and some shale and sandstone. | 3,500-4,000 |
| Do | Katalla formation | Shale, sandstone, and conglomerate. | 2,000+ |
| Mesozoic or Paleozoic | | Slate, graywacke, and volcanic rocks. | |

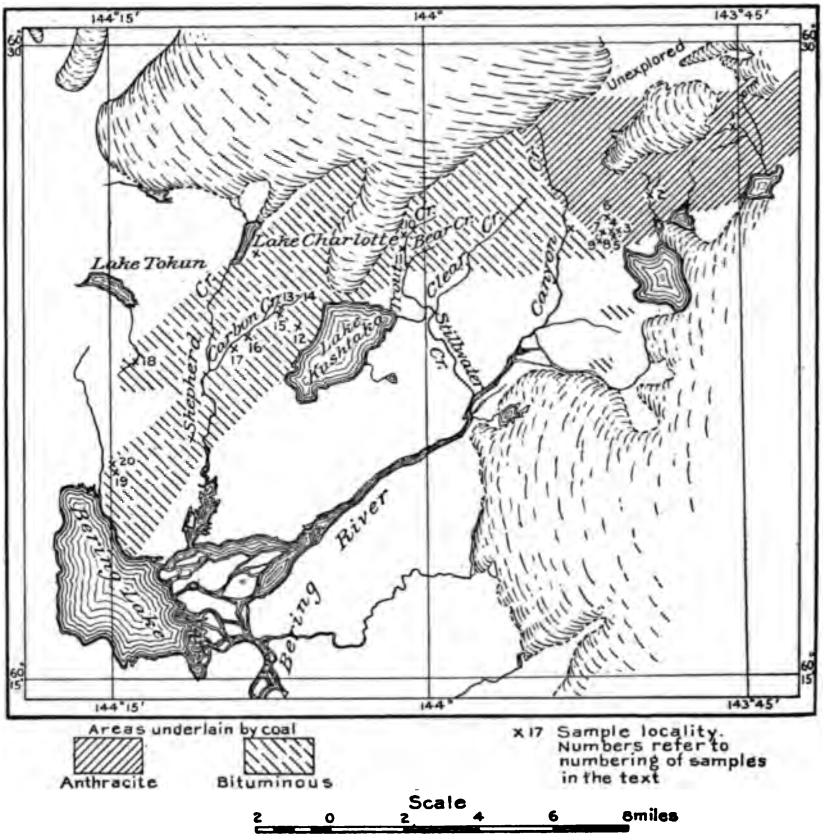

FIG. 2.—Map of Bering River coal field, showing areas underlain by coal.

*Section of upper part of Kushtaka (coal-bearing) formation on Kushtaka Ridge.*

| | Ft. | in. |
|---|---|---|
| Contact with overlying formation. | | |
| Shale, coaly | | 2 |
| Shale | | 8 |
| Coal (shaly at bottom for 1 foot) | 3 | 8 |
| Shale, dark, but weathering brownish red | 9 | |
| Coal | 4 | 8 |
| Shale, with some coal | 9 | |
| Shale, blue, sandy | 48 | |
| Arkose | 231 | |
| *Shale, dark* | 9 | |

| | Ft. | in. |
|---|---|---|
| Shale, carbonaceous, with bands of coal 6 to 12 inches thick (exposure poor) | 45 | |
| Arkose, flaggy and fine grained, with some sandstone | 93 | |
| Shale, carbonaceous | 2 | |
| Coal | 2 | 4 |
| Shale, carbonaceous | | 6 |
| Arkose, flaggy, fine grained | 127 | |
| Shale, fine grained, blue | 291 | |
| Coal (exposure not good, estimated with shale) | 11 | |
| Arkose, flaggy, and shale | 50 | |
| Shale, carbonaceous, with coal (exposure obscure) | 23 | |
| Arkose, flaggy | 163 | |
| Shale with thin coal streaks one-half inch thick | 5 | |
| Coal | | 6 |
| Shale | 1 | |
| Coal | | 6 |
| Shale | 2 | |
| Coal | | 5 |
| Shale and flaggy arkose | 84 | |
| Coal | 3 | |
| Shale | | 6 |
| Coal | | 6 |
| Shale | | 6 |
| Coal | | 1 |
| Arkose, flaggy, and shale | 68 | |
| Coal, clean | 8 | |
| Shale | 36 | |
| Arkose, flaggy, with some shale | 198 | |
| Coal | 1 | |
| Shale | 2 | |
| Coal, clean | 5 | |
| Shale | 287 | |
| Arkose | 130 | |
| Shale | 87 | |
| | 2,043 | |

(Anticlinal axis on divide at head of Carbon Creek.)

*Section of upper part of Kushtaka formation on ridge between Trout and Clear creeks.*

| Contact with overlying formation. | Ft. | in. |
|---|---|---|
| Arkose, possibly with thin beds of coal | 60 | |
| Coal (5 to 6 feet thick), with shale | 10 | |
| Arkose | 83 | |
| Coal | 1 | |
| Arkose, thin bedded and shaly | 92 | |
| Shale, dark | 29 | |
| Coal | 1 | |
| Shale, dark, with lime concretions | 51 | |
| Coal | | 4 |
| Shale | | 4 |
| Coal | 10 | |
| Shale | 1 | |
| Coal | 2 | 4 |
| Shale, dark, with concretions, thin beds of arkose, and several beds of coal whose thickness could not be determined | 155 | |
| Arkose, thin bedded | 33 | |
| Shale, dark | 12 | |
| Coal | 12 | |
| Shale | 8 | |
| Arkose | 52 | |
| Shale, with some coal | 25 | |
| Arkose | 165 | |
| Shale, dark | 12 | |
| | 815 | |

## STRUCTURAL FEATURES.

There are two types of structure in this coal field, the line of separation passing through the valley of Canyon Creek and agreeing very closely with the division between the anthracite and bituminous coal.

The western district, in which the coal is semibituminous or semianthracite, is characterized by open and for the most part fairly regular folds, of which two major and several minor synclines occur within the area of coal-bearing rocks. This structure is illustrated in fig. 3. Some faults are present.

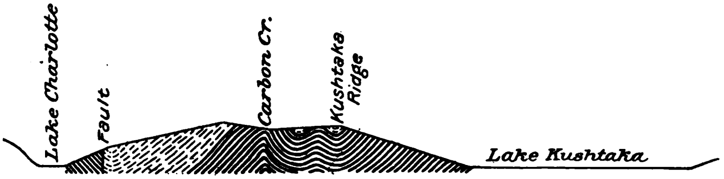

FIG. 3.—Section from Lake Charlotte to Lake Kushtaka.

The eastern district, which lies to the east of Canyon Creek and Carbon Mountain and which contains anthracite coal, is characterized by almost uniformly northwestward dips, frequently at low angles, and by numerous dikes and sills of igneous rock. The structure of this end of the field is hardly as simple as the low and apparently uniform dips seem to indicate. What seems to be monoclinal dip is in reality sometimes close overturned folding in which the rocks are bent back on themselves so that the opposite sides of a fold are parallel. The rocks are also broken locally by faults, which cause a repetition of the beds; while there are also places where the beds are involved in complex close folding with steep and not overturned dips.

## COAL SEAMS.

### ANTHRACITE.

The exposures of anthracite at the extreme east end of the area mapped are for the most part well up the mountain sides and inaccessible. The following seams were measured and sampled:

*Section 1¾ miles upcreek from Fourth Berg Lake, elevation 1,850 feet.*

| | Ft. | in. |
|---|---|---|
| Dark shale roof. | | |
| Coal [a] | | 8 |
| Coaly shale | | 4 |
| Coal [a] | | 11 |
| Coaly shale | | 3 |
| Coal [a] | | 8 |
| Shale floor. | | |
| | 2 | 10 |

Strike, N. 76° W.; dip, 55° SW.

*Section in gulch at head of Second Berg Lake.*

| | Ft. | in. |
|---|---|---|
| Sandstone roof. | | |
| Coal, bony | | 6 |
| Coal, hard and bright [b] | 2 | 2 |
| Sandy shale floor. | | |

Strike, N. 85° W.; dip, 32° NE.

About a mile above this, on the north side of the valley and just below the hanging glacier, a 7-foot bed of anthracite is reported. The sample shown to the writer is very bright, hard, and not crushed at all.

The best exposures of anthracite seen by the writer are in Carbon Mountain, where the following sections were measured.

---

[a] Included in sample No. 1, p. 74.

[b] Included in sample No. 2, p. 74.

*Section in third (eastern) opening on hillside trail on east side of Carbon Mountain.*

| | Ft. | in |
|---|---|---|
| Shale roof. | | |
| Coal | 10 | 6 |
| Shale floor. | | |
| Strike, N. 60° E.; dip, 28° NW. | | |

*Section on east side of Carbon Mountain, second opening from west end of hillside trail.*

| | Feet. |
|---|---|
| Shale roof. | |
| Coal[a] | 15+ |
| Shale floor. | |
| Strike, N. 77° E.; dip, 22° NW. | |

It was not possible to obtain a complete measurement of this coal, which is reported to be 23 to 25 feet thick.

*Section on east side of Carbon Mountain, first opening from west end of hillside trail.*

| | Ft. | in. |
|---|---|---|
| Coal[b] | 10 | 6 |

These three sections are all probably on the same seam, which the owners claim to have followed along the mountain side for 2 miles, finding in this distance thicknesses ranging from 9 to 25 feet.

About 200 feet below this is another seam which is said to vary in thickness from 4 to 11 feet. The following section was measured by the writer:

*Section of seam 200 feet below hillside trail on east side of Carbon Mountain.*

| | Ft. | in. |
|---|---|---|
| Shale roof. | | |
| Coal[c] | 4 | 8 |
| Shale floor. | | |
| Strike N. 80° W., dip 30° NE. | | |

Several other seams are exposed lower down the face of the mountain.

An important and apparently very persistent seam is exposed along the west side and near the top of Carbon Mountain. It is possibly the same as the upper seam, referred to above, on the east side of the mountain. The following sections were measured:

*Section at north end of hillside trail on west side of Carbon Mountain.*

| | Feet. |
|---|---|
| Shale roof. | |
| Coal[d] (bright, clean, and often iridescent) | 15+ |
| Shale floor. | |
| Strike N. 84° W., dip 25° NE. | |

*Section at south end of hillside trail on west side of Carbon Mountain.*

| | Feet. |
|---|---|
| Shale roof. | |
| Coal[e] | 10 |
| Shale floor. | |
| Strike N. 52° E., dip 6° SE. | |

The following sections, taken a little farther south on the west side of the same ridge, show a coal which has the physical characteristics of the anthracite at the other openings in the vicinity, but whose analyses indicate a semianthracite. From the structural relations it seems probable that one of the seams corresponds to the lower coal described from the eastern side of the mountain.

*Section in opening near crest (west side) of Carbon Mountain between trails.*

| | Ft. | in. |
|---|---|---|
| Shale roof. | | |
| Coal[f] | 5 | 3 |
| Shale floor. | | |

---

[a] Included in sample No. 3, p. 74.

[b] Included in sample No. 4, p. 74.

[c] Included in sample No. 5, p. 74.

[d] Included in sample No. 6, p. 74.

[e] Included in sample No. 7, p. 74.

[f] Included in sample No. 8, p. 74.

*Section in opening 50 feet below the section just given.*

| | Ft. | in. |
|---|---|---|
| Shale roof. | | |
| Coal, impure | | 3 |
| Coal[a] (good and hard) | 2 | 10 |
| Shale floor. | | |

Strike N. 82° E., dip 38° NW.

Numerous outcrops of anthracite (mostly poorly exposed) were seen on the banks of Canyon Creek for a distance of 2 or 3 miles below the glacier. The following sections represent the best of these outcrops:

*Section at source of Canyon Creek (west bank).*

| | Feet. |
|---|---|
| Coal | 5 |

*Section on west bank of Canyon Creek, 500 feet below glacier.*

| | Feet. |
|---|---|
| Coal | 3 |

### SEMIANTHRACITE OR SEMIBITUMINOUS.

The valley of Clear Creek contains many good outcrops of coal. The following sections represent a very small part of the exposures and openings:

*Section in stripping on northwest bank of Clear Creek above falls.*

| | Feet. |
|---|---|
| Coal | 47 |

*Section in stripping south of the one given above.*

| | Feet. |
|---|---|
| Coal | 31 |

*Section in opening at foot of Clear Creek falls.*

| | Feet. |
|---|---|
| Coal | 16 |

Strike N. 65° E., dip 49° NW.

*Section of coal 2.9 miles above mouth of Clear Creek.*

| | Feet. |
|---|---|
| Sandy shale | 3 |
| Coal | 4 |
| Sandy shale floor. | |

Strike N. 90° E., dip 67° N.

This is the lowest coal exposed in the region. There is an intrusive mass in very close proximity to the coal, but it does not seem to have altered it.

Several workable seams are exposed on Trout Creek. The following sections, arranged in stratigraphic order, beginning with the highest, were measured.

*Section in tunnel on Trout Creek opposite house.*

| | Feet. |
|---|---|
| Shale roof. | |
| Coal[b] | 8 |
| Shale floor. | |

Strike N. 85° W., dip 28° NE.

*Section in tunnel 500 feet below house on Trout Creek.*

| | Ft. | in. |
|---|---|---|
| Coal | 4 | 6 |

---

[a] Included in sample No. 9, p. 74.

[b] Included in sample No. 10, p. 74.

### *Section in long tunnel one-fourth mile below house on Trout Creek.*

| | Feet. |
|---|---|
| Shale roof. | |
| Coal[a] | 33 |
| Shale floor. | |

Strike N. 65° E., dip 38° NW.

### *Section in tunnel 1,500 feet below house on Trout Creek.*

| | Ft. | in. |
|---|---|---|
| Arkose roof. | | |
| Coal | 7 | 7 |
| Arkose floor. | | |

### *Section on small drain into Trout Creek from the west.*

| | Ft. | in. |
|---|---|---|
| Shale roof | | |
| Coal | 6 | |
| Shale floor (strike N 2° W., dip 24° SW.). | | |
| Concealed | 20 | |
| Coal (strike N. 25° E., dip 39° NW.) | 3 | 6 |
| Concealed | 15 | |
| Shale roof. | | |
| Coal | 12+ | |
| Shale floor (strike N. 15° E., dip 27° NW.). | | |

The following sections are all in the group of hills between Lake Kushtaka and Shepherd Creek:

### *Section on east side of Kushtaka Ridge (elevation 1,335 feet).*

| | Ft. | in. |
|---|---|---|
| Coal | 12-15 | |
| Shale | 1 | |
| Coal | 2 | 6 |
| Shale | 2 | 6 |
| Bone | 2 | 4 |
| Coal | 2 | 6 |
| Bone | | 6 |
| Coal | 1 | |
| Bone | | 4 |
| Coal | 2 | 6 |
| | 27-30 | 2 |

Strike N. 22° E., dip 58° NW.

### *Section on east side of Kushtaka Ridge (elevation 1,630 feet).*

| | Ft. | in. |
|---|---|---|
| Shale roof. | | |
| Bone | | 8 |
| Coal | 3 | 8 |
| Shale | | 1 |
| Coal | 3 | 4 |
| Bone | | 3 |
| Coal | 1 | 8 |
| Bone | | 5 |
| Coal | 1 | |
| Shale | | 4 |
| Coal | | 11 |
| Bone | | 2 |
| Dark shale floor. | | |
| | 12 | 6 |

Strike N. 45° E., dip 68° NW.

### *Section in tunnel on west face of Kushtaka Ridge (elevation 790 feet.)*

| | Feet |
|---|---|
| Shale roof. | |
| Coal[b] | 18 |
| Shale floor. | |

Strike N. 65° E., dip 45° NW.

---

[a] Included in sample No. 11, p. 74.

[b] Included in sample No. 12, p. 74.

*Section of coal on northwest bank of Queen Creek.*

| | Feet. |
|---|---|
| Shale roof. | |
| Coal[a] | 27 |
| Shale (pocket?) | 7 |
| Coal | 2 |
| Shale | 10 |
| Coal[b] | 31 |
| Shale floor. | |
| | 77 |

*Section on east branch of Queen Creek.*

| | Ft. | in. |
|---|---|---|
| Shale roof. | | |
| Coal | 1 | 1 |
| Shale | 3 | 6 |
| Coal | 2 | 2 |
| Shale with coal streaks | 1 | 6 |
| Coal | 3 | 6 |
| Shale | | 9 |
| Coal | 6 | 8 |
| Shale | 3 | 6 |
| Coal | 11 | |
| | 33 | 8 |

*Section on east branch of Queen Creek.*

| | Ft. | in. |
|---|---|---|
| Shale roof. | | |
| Coal[c] | 17 | |
| Shale | 41 | |
| Coal | 4 | |
| Shale | 5 | |
| Coal | 3 | |
| Shale | 2 | 6 |
| Coal | 26 | |
| Carbonaceous shale. | | |
| | 98 | 6 |

*Section on east branch of Queen Creek.*

| | Feet. |
|---|---|
| Coal | 14 |
| Shale | 2 |
| Coal | 16 |
| | 32 |

*Section in stripping on north side of Carbon Creek above the tunnel (elevation 830 feet).*

| | Feet. |
|---|---|
| Shale roof. | |
| Coal | 8 |
| Shale floor. | |

Strike N. 50° E., dip. 45° NW.

*Section in tunnel on south bank of Carbon Creek.*

| | Feet. |
|---|---|
| Arkose roof. | |
| Coal[d] | 8-11 |
| Shale floor. | |

*Section in tunnel on small tributary on south side of Carbon Creek near its mouth.*

| | Ft. | in. |
|---|---|---|
| Dark shale | 2 | |
| Coal | 19 | 7 |
| Arkose | 10 | |

Strike N. 90° E., dip 78° N.

The following sections are all west of Shepherd Creek:

*Section in upper tunnel on Tokun Creek.*

| | Feet. |
|---|---|
| Argillaceous sandstone roof. | |
| Coal | 6 |

Strike N. 78° W., dip 40° NE.

---

[a] Included in sample No. 13, p. 74.

[b] Included in sample No. 14, p. 74.

[c] Included in sample No. 15, p. 74.

[d] Included in sample No. 16, p. 74.

*Section in lower tunnel on Tokun Creek.*

| | Ft. | in. |
|---|---|---|
| Arkose roof. | | |
| Coal[a] | 6 | 8 |
| Shale floor. | | |

*Section at head of gorge on Trail Creek.*

| | Ft. | in. |
|---|---|---|
| Sandstone roof. | | |
| Coal | 2 | 6 |
| Sandstone floor. | | |

Strike N. 15° W., dip 55° NE.

*Section in opening on cliffs of small creek, 1 mile north of Bering Lake.*

| | Feet. |
|---|---|
| Arkose roof. | |
| Coal[b] | 3 |
| Coal and shale | 3 |
| Coal[b] | 4 |
| Sandy shale floor. | |

Strike N. 20° W., dip 25° NE.

*Section in Christopher's tunnel, 1 mile north of Bering Lake.*

| | Ft. | in. |
|---|---|---|
| Coal (top concealed) | 2 | |
| Shale | 1 | 6 |
| Coal[c] | 8 | 6 |
| Sandstone floor. | | |

Strike N. 70° E., dip 35° NW.

## CHARACTER OF THE COAL.

### PHYSICAL PROPERTIES.

All of the coal east of the crest of Carbon Mountain and fully half of that in the valley of Canyon Creek, so far as can be judged from surface exposures, is true anthracite. Numerous specimens have been seen which are hard and strong and which apparently possess all the physical characteristics of Pennsylvania anthracite. On the other hand, the surface exposures and shallow excavations usually show a soft, friable mass of coal, which gives little indication of anthracitic character. It is impossible to tell whether the coal in these exposures will be found hard and unbroken below the zone of surface disintegration or whether it is all badly crushed and shattered. The value of this end of the field (that is, the possibility of profitable mining) depends largely on this question, for when an anthracite is badly crushed its market value is far more seriously impaired than that of a bituminous coal would be.

The semianthracite or semibituminous coal is all of a friable nature and resembles the softer bituminous coals of the Eastern States. Most of the beds have been severely crushed and sheared, and the coal is certain to be badly broken up in mining and shipping. This is not such a great detriment in this class of coal as it is with anthracite, for some of it will probably be made into coke, while that which is used as steam coal will fuse and cake as soon as it is put into the furnace, thus preventing the loss of slack through the grates.

### CHEMICAL AND CALORIMETRIC TESTS.

The following analyses and calorimetric[d] tests have been made on samples collected in a uniform manner during the last season. These samples were obtained by making a cut across a fresh face of the coal from roof to floor, cutting down only the coal which would probably be loaded and leaving out such impurities as could be separated in the ordinary practices of actual mining. The parts of each seam which went into the sample are indicated in the local sections. These analyses[e] were made by F. M. Stanton, of the United States Geological Survey coal-testing plant at St. Louis, Mo. Other analyses are given in earlier reports.[f]

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[a] Included in sample No. 18, p. 74.

[b] Included in sample No. 19, p. 74.

[c] Included in sample No. 20, p. 74.

[d] A calorie is the amount of heat necessary to raise the temperature of 1 pound of water 1° C. It is equal to 1.8 British thermal units.

[e] For methods of analysis see Bull. U. S. Geol. Survey No. 261, 1905, pp. 30–31.

[f] Martin, G. C., The Petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: Bull. U. S. Geol. Survey No. 250, 1905, p. 32; Bering River coal field: Bull. U. S. Geol. Survey No. 259, 1905, pp. 146–149.

*Analyses of Bering River coals.*

| No. of sample. | Locality. | Thickness of coal, in feet. | Moisture in air-dried sample. | Total moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Calories per pound of coal. | Recalculated. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Fuel elements. | | Fuel ratio. |
| | | | | | | | | | | Volatile matter. | Fixed carbon. | |
| 1 | 1¾ miles above Fourth Berg Lake | 2.67 | 2.97 | 7.67 | 5.78 | 66.03 | 20.52 | 2.90 | ........ | 8.05 | 91.95 | 11.42 |
| 2 | Gulch at head of Second Berg Lake | 2.17 | 1.84 | 3.74 | 5.41 | 85.92 | 4.93 | 1.10 | ........ | 5.92 | 94.08 | 15.88 |
| 3 | Carbon Mountain, east side, second opening from west on hillside trail | 15 + | 2.23 | 8.33 | 6.36 | 82.00 | 3.31 | 1.11 | ........ | 7.20 | 92.80 | 12.89 |
| 4 | Carbon Mountain, east side, first opening from west on hillside trail | 10.5 | .69 | 13.89 | 5.01 | 73.87 | 7.23 | .82 | 6,743 | 6.35 | 93.65 | 14.75 |
| 5 | Carbon Mountain, east side, 200 feet below hillside trail | 4.7 | 1.06 | 7.26 | 6.64 | 75.89 | 10.21 | 1.27 | ........ | 8.05 | 91.95 | 11.43 |
| 6 | Carbon Mountain, west side, north end of hillside trail | 15 | .73 | 5.93 | 6.76 | 81.47 | 5.84 | .82 | ........ | 7.66 | 92.34 | 12.05 |
| 7 | Carbon Mountain, west side, south end of hillside trail | 10 | 1.31 | 8.31 | 7.12 | 82.43 | 2.14 | 1.05 | ........ | 7.95 | 92.05 | 11.58 |
| | Average of analyses 1-7 | ........ | 1.55 | 7.88 | 6.15 | 78.23 | 7.74 | 1.30 | ........ | 7.31 | 92.69 | 12.86 |
| 8 | Carbon Mountain, west side, near crest at trail | 5.25 | 2.94 | 7.94 | 9.20 | 78.53 | 4.33 | .79 | ........ | 10.49 | 89.51 | 8.54 |
| 9 | Carbon Mountain, west side, 50 feet below last | 2.85 | 2.93 | 4.43 | 10.14 | 80.78 | 4.65 | .51 | 7,578 | 11.15 | 88.85 | 7.97 |
| | Average of analyses 8-9 | ........ | 2.94 | 6.18 | 9.67 | 79.66 | 4.49 | .65 | ........ | 10.82 | 89.18 | 8.26 |
| 10 | Trout Creek, tunnel opposite house | 8 | .81 | 2.11 | 16.58 | 79.68 | 1.63 | .78 | ........ | 17.22 | 82.78 | 4.81 |
| 11 | Trout Creek, tunnel ¼ mile below house | 33 | .94 | 6.34 | 14.29 | 69.55 | 9.82 | .64 | ........ | 17.04 | 82.96 | 4.87 |
| 12 | Kushtaka Ridge, 710 feet above lake | 18 | .78 | 2.68 | 11.06 | 73.31 | 12.95 | 5.27 | ........ | 13.11 | 86.89 | 6.63 |
| 13 | Queen Creek opening, upper seam | 27 | 1.23 | 4.23 | 14.03 | 79.75 | 1.99 | .96 | ........ | 14.96 | 85.04 | 5.68 |
| 14 | Queen Creek opening, lower seam | 31 | 1.06 | 5.66 | 13.65 | 76.81 | 3.88 | .77 | ........ | 15.09 | 84.91 | 5.63 |
| 15 | East branch of Queen Creek | 17 | 1.04 | 4.94 | 13.34 | 77.29 | 4.43 | .83 | ........ | 14.72 | 85.28 | 5.79 |
| 16 | Tunnel on south side of Carbon Creek | 11 | .52 | 4.22 | 13.37 | 78.80 | 3.61 | 1.56 | ........ | 14.51 | 85.49 | 5.89 |
| 17 | Tunnel on small branch of Carbon Creek | 19.6 | .55 | 5.95 | 13.01 | 76.12 | 4.92 | .61 | ........ | 14.60 | 85.40 | 5.85 |
| 18 | Lower tunnel on Tokun Creek | 6.7 | .65 | 4.35 | 11.97 | 73.34 | 10.34 | 1.13 | ........ | 14.03 | 85.97 | 6.13 |
| 19 | Opening on creek, 1 mile north of Bering Lake | 10 | .83 | 6.03 | 12.98 | 78.40 | 2.59 | .70 | ........ | 14.20 | 85.80 | 6.04 |
| 20 | Tunnel on creek, 1 mile north of Bering Lake | 8.6 | .74 | 5.84 | 11.74 | 60.21 | 22.21 | 3.36 | ........ | 16.32 | 83.68 | 5.13 |
| | Average of analyses 10-20 | ........ | .83 | 4.76 | 13.27 | 74.84 | 7.12 | 1.51 | ........ | 15.07 | 84.93 | 5.68 |

It will be noticed that in most of these samples there was a large amount of total moisture, the greater part of which was driven off by air drying.[a] Under most circumstances this would be regarded as excessive and not characteristic of fair samples. But in view of the large amount of underground water which the rocks of this region contain and the heavy rainfall, it seems probable that the total moisture of these analyses will represent approximately the proportion which the coal will contain in uncovered cars when it reaches tide water.

The first seven analyses in this table are characteristic of the anthracite coal. They show it to be of excellent quality, some of the samples, especially of the thicker beds, being remarkably low in ash.

Samples No. 8 and No. 9, which are from the west slope of Carbon Mountain, near the crest and near the southern edge of the coal belt, are higher in volatile matter than the rest of the coal in this part of the field, and should probably rank as semianthracite rather than as true anthracite. They are, nevertheless, of excellent quality, being purer, regarding both ash and sulphur, than some of the anthracite. They resemble the anthracite in appearance and will probably be classed as such by the trade.

The remaining analyses indicate a coal which is on the border line between semibituminous and bituminous, according to the definitions of Frazer in the reports of the Second Pennsylvania Survey, or between semianthracite and semibituminous, according to the more generally accepted trade classification. The coal is very close in composition to the Pocahontas (West Virginia) coal and to some of the other similar coals of the Applachians and of Arkansas. Comparisons with other coals are made in the tables of analyses and discussions in another paper in this bulletin.[b]

### COKING TESTS.

The coal from the 33-foot bed on Trout Creek (see p. 71) was tested in the following manner: A hot wood fire was built in a pit dug for the purpose and lump coal gradually added until about 600 pounds of coal was burning. Then about a ton of coal was added. The sides of the pile were banked with stones and dirt, the top and ends being left open for draft. After several hours the ends were covered, and only a small opening at the top was left uncovered to let the smoke escape. Four days later, when the smoke ceased to come off, the pile was opened and the fire extinguished. The resulting coke was firm, strong, and porous, and had a good ring and luster. The test showed conclusively that an excellent coke can be made from this coal.

Coal from many of the other seams was tested more crudely, and it was found that practically all of the coal here classed as semibituminous possesses such coking qualities that there is little or no doubt that by proper treatment a good coke can be made from almost any of it.

## CONDITIONS FOR MINING.

The problems which will affect the cost of mining in this region include the friable character of the coal, steep dips, complicated structure, variability in thickness, possible lack of persistence of the seams, the occurrence of explosive gases, and large amounts of underground water.

The friability of the coal, if it persists beyond the zone of surface weathering, will very seriously affect the market value of the anthracite. If the anthracite yields a large proportion of slack, and especially if it crushes during transportation, it will be at a decided disadvantage in the market. No openings on the anthracite have as yet been driven beyond the zone of surface disintegration, so it is impossible to tell whether or not the coal below the surface is sufficiently firm to stand handling. In some of the stream beds there are numerous pieces of anthracite which are firm and hard, indicating either that these pieces came from fresh exposures, where the coal was not softened and broken up by frost and other weathering, or that there are beds which are better than those which have been prospected. An opening driven to a sufficient depth on one of the beds would settle this question.

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[a] Each sample of coal, after a rapid preliminary crushing to about one-fourth inch size and reduction in bulk by quartering where desirable, was weighed and then exposed to the air for about twenty-four hours, or until the loss of weight on further exposure became slight. The loss of weight thus determined constitutes the "loss on air drying," and is represented in the table of analyses by the difference between "total moisture" and "moisture in air-dried sample."

[b] Markets for Alaska coal, pp. 18-29.

The semibituminous coals which possess the property of coking are not so seriously affected by the tendency to crush, for, as has already been pointed out, they will probably be used in part for the manufacture of coke, and when used as steam or other heating coal they will fuse and form a solid mass as soon as put in the furnace.

Steep dips do not make mining impossible or even excessively costly. They introduce no mining problems which have not already been successfully met in other fields.

The possible overturned folds and the faults introduce problems the scope of which can perhaps be determined only by exploration of the seams in depth. It seems probable that there are areas within the field in which, because of these difficulties, the coal can not be successfully mined. These must be determined by careful surface prospecting, followed by either boring or tunneling at critical points. The anthracite field is especially liable to be affected by these difficulties, which, on the other hand, will be compensated for, in part, at least, by the greater value of the coal.

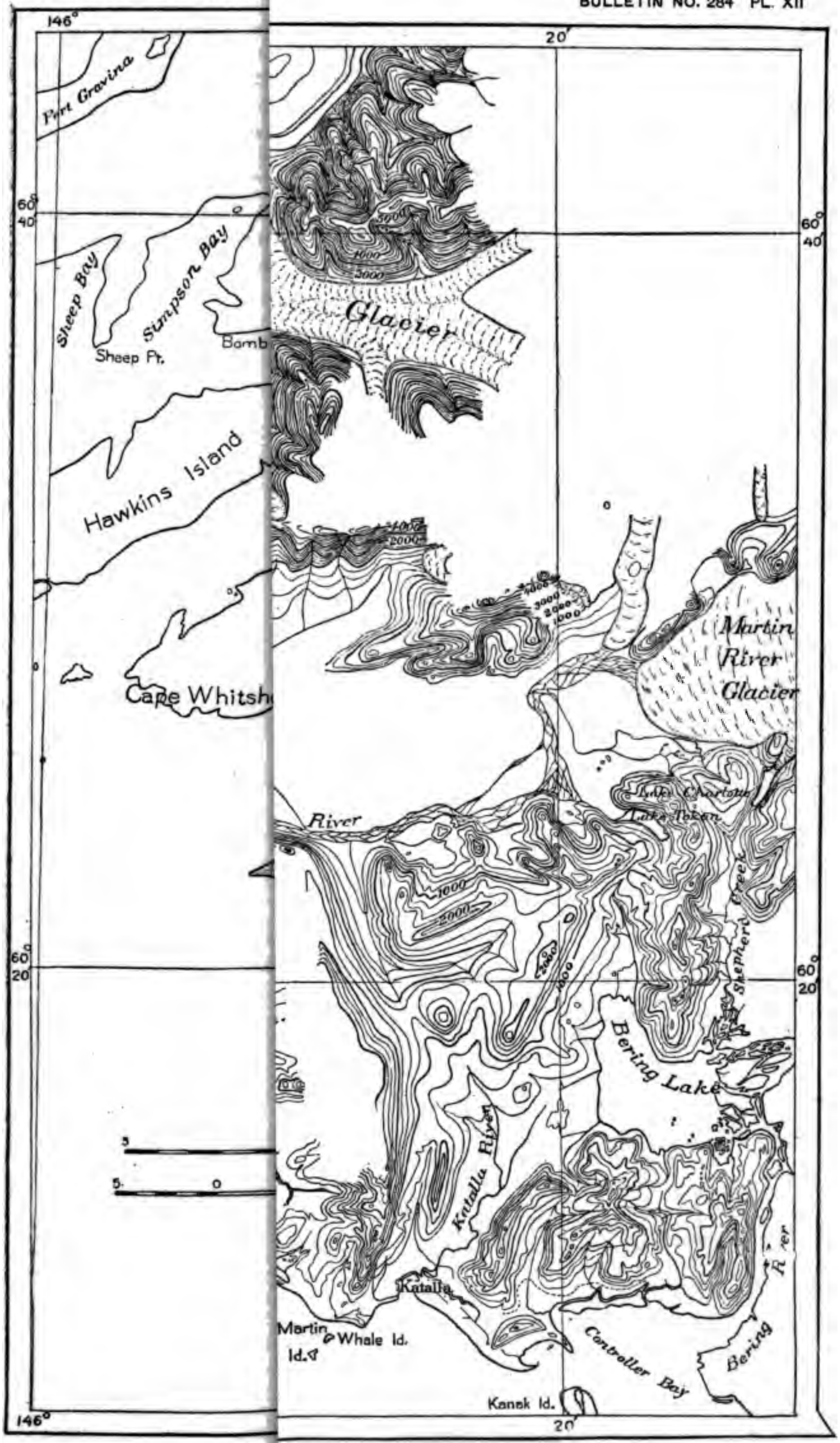
Variability in thickness of the seams, especially of the thicker ones, may be considered an ever-present problem, the exact magnitude of which can be determined only by underground exploration. It is the current belief in the region that the seams will assume constant thicknesses and attitudes as soon as they are followed under a heavy cover of overlying rock. Such is not necessarily the case. The swellings and pinchings of the coal do not depend on the nature of the surface of the ground, but on the mode of formation of the coal bed and on the structure of the rocks. Faults or breaks in the coal, pockets, and squeezes are just as liable to be found under the center of a uniform plateau as on the edges of canyons, and must be determined by the position of the rocks in solid outcrop or by boring or tunneling, and not by the character of the surface of the ground. It is certain that they will always be a serious problem in mining in this region; but, on the other hand, it is likely that they will in large degree be compensated for by numerous areas of excessively thick beds and by the high fuel value of the coal.

It is probable that underground water will be encountered in large amounts, due to the abundance of surface water and the deep fracturing of the rocks. Fortunately, there is a large amount of coal above the general drainage level, so it will not be necessary to resort to shafting for a long time. Consequently the water, although it may be very annoying, will not add materially to the expense of mining.

Gas has been encountered in several of the longer tunnels and will have to be considered a factor in the cost of mining. It will probably be necessary to resort both to very careful ventilation and to the use of safety lamps. Some legislative provision should be made for this before mining begins.

## TRANSPORTATION AND MARKETS.

There will be no market for the Bering River coal, except in a limited way for fuel and blacksmith coal at the oil wells, until shipping facilities are provided. Four plans have been considered for shipping the coal. The first (or oldest) involves the building of from 23 to 35 miles of railroad and the construction of long wharves to deep water in Controller Bay. The second includes wharves on deep water near Katalla, and from 20 to 35 miles of railroad to reach the coal. The third plan is to use a harbor on Prince William Sound (probably at Cordova Bay) which can be reached (see Pl. XII) by about 85 miles of road from the nearest coal, by way of the Shepherd Creek Valley and the 350-foot pass leading northwest from Lake Charlotte toward the Copper River drainage. A fourth plan is to build the railroad to shoal water on Controller Bay or Bering River and transfer the coal by shallow-draft barges to wharves or anchorage on deep, sheltered water.


146°
20′
Port Gravina
60° 40′
Sheep Bay
Simpson Bay
Sheep Pt.
Bomb
Glacier
5000
4000
3000
Hawkins Island
4000
2000
4000
3000
2000
1000
Martin River Glacier
Cape Whitsh
Lake Charlotte
Lake Tokun
River
1000
2000
3000
Shepherd Creek
60° 20′
Bering Lake
Katalla River
Katalla
Martin Id.
Whale Id.
Controller Bay
Bering River
Kanak Id.
146°
20′

D.

All these plans are feasible, although the last would have the disadvantage of possible interference by ice for a short time in the winter. The choice must depend on questions of cost, including both the actual cost of handling the coal and the interest on the original investment. Some of the projects involve the extension of the road to the copper fields of the interior, which would of course greatly modify the conditions. There are no difficulties connected with building a railroad from any point on Controller Bay or Katalla Bay to the coal field. The important factors in the problem are, on one hand, the relative merits of a local harbor, questions of depth of water, holding ground, shelter from storms and from ice, and cost of improvements being considered, and, on the other hand, the cost of a longer road to a possibly better harbor farther west.

# COPPER AND OTHER MINERAL RESOURCES OF PRINCE WILLIAM SOUND.

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By U. S. Grant.

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## INTRODUCTION.

Prince William Sound is an embayment extending northward from near the center of the north side of the Gulf of Alaska, and lies just west of the Copper River delta and east of Cook Inlet (Pl. II). It is included between west longitude 145° 35′ and 148° 50′, and between north latitude 59° 50′ and 61° 25′. (See fig. 4.) The extreme east and west length of the sound, from the head of Cordova Bay on the east to the head of Port Nellie Juan on the west, is 108 miles, and its extreme north and south dimension, from the head of College Fiord on the north to the south end of Montague Island on the south, is 107 miles. Instead of being strictly a sound, in the ordinary usage of this term, Prince William Sound is a bay or gulf, which includes many islands and whose coast line is indented by numerous long, narrow inlets or fiords. The coast is rugged and rocky and commonly rises abruptly from the water's edge to altitudes of from 1,000 to 3,000 feet, while inland a few miles are mountains from 4,000 to 10,000 feet in height. These mountains surround the sound on the west, north, and east and form part of the Chugach Range. The higher peaks are continually snow covered, and glaciers descend into many of the valleys. Along the north and west sides of the sound, at the heads of various fiords, a number of these glaciers reach tide water.

The principal town of the district is Valdez (see fig. 4), situated at the northeast corner of Prince William Sound, at the head of Port Valdez. It is the outfitting point for the sound and also for the Copper River region and the placer fields to the north. Canneries are located at Orca and Odiak, while at Ellamar, on Virgin Bay, and at Latouche, on Latouche Island, there are producing mines.

Prospecting for copper on the shores of Prince William Sound has been going on for about ten years, and earlier than this sporadic search for ores is reported. In 1904 and 1905 prospecting was especially active. Mining is being carried on at two points—at Ellamar and on Latouche Island. During the summer of 1905 from 1,200 to 2,000 tons of copper ore were shipped monthly to the smelter at Tacoma, Wash. The main part of this came from the Gladhaugh mine at Ellamar.

In 1898 a party of the United States Geological Survey made a rapid reconnaissance of the geology and mineral resources of Prince William Sound,[a] and in 1900 further information concerning this region was obtained by the Survey.[b] During the summer of 1905 the writer, assisted by Sidney Paige, made a more detailed reconnaissance of the general geology and mineral resources of the sound. The whole eastern shore from Valdez to

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[a] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River District, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 341–423.

[b] Schrader, F. C., and Spencer, A. C., The Geology and Mineral Resources of a Portion of the Copper River District, Alaska; a special publication of U. S. Geol. Survey, 1901, 94 pp.

Orca was studied, and practically all the copper prospects were examined. On the western and northern portions of the sound the work on the general geology was less detailed, but nearly all the copper prospects were visited. The present report is a preliminary statement concerning the results of this work and treats especially of the copper deposits. It is expected that a more detailed report on the general geology and mineral resources of Prince William Sound will be issued later.

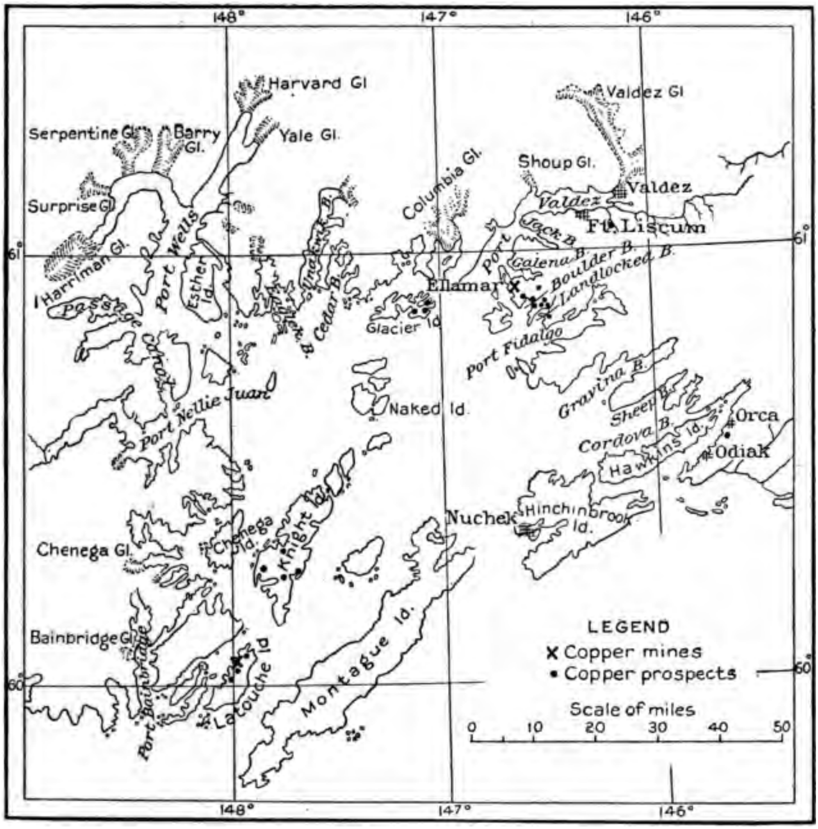

FIG. 4.—Sketch map of Prince William Sound region.

## GENERAL GEOLOGY.

The sedimentary rocks of Prince William Sound consist essentially of graywackes and slates. In places the graywackes approach arkoses and sandstones, or even quartzites, and the slates approach shales, but three-fourths of the sedimentary rocks of the sound can be conveniently and accurately included under the names of graywacke, graywacke-slate, and slate. In color these are dark gray or even black, the coarser rocks being usually the lightest colored and the slates the darkest. There are a few inconspicuous black limestone beds and some conspicuous conglomerates. The latter have commonly a coarse graywacke matrix with pebbles of various kinds, among which (1) graywacke, (2) fine-grained igneous rocks, commonly rather acidic, (3) flinty slates, and (4) vein quartz are the most numerous. In some places the sediments are schistose and more crystalline, but no markedly crystalline schists occur except in the immediate vicinity of granitic intrusions.

The igneous rocks consist mainly of (1) granitic masses intruded into the surrounding sediments, (2) aplitic dikes, (3) basic dikes, and (4) basic lava flows. These latter have been altered, sometimes rendered schistose, and are referred to as greenstones. They are the most abundant and the most characteristic igneous rocks of the region. Many of the flows consist in considerable part of irregular ellipsoidal masses 1 to 10 feet in diameter, closely resembling the ellipsoidal greenstones of the Lake Superior region.

The sedimentary rocks and the lava flows have been completely, complexly, and usually closely folded, and a cleavage has been developed, especially in the finer sediments. The folding has been so close that in most parts of the district the cleavage practically agrees with the bedding. The dips and strikes vary considerably. The former average above 45°, and frequently are 60° to 90°. About Port Valdez the direction of dip is consistently toward the north, the folds being overturned toward the south. Locally the strike is rather constant, and often runs parallel with the physiographic features, as along the eastern stretch of Port Valdez, where the strike agrees with the axis of the bay, and also on Latouche Island, where the strike is parallel with the length of the island.

The sedimentary rocks of Prince William Sound are separable into at least two unconformable series of nearly similar lithological characters. The older of these series, named by Schrader, the Valdez,[a] is typically developed about the eastern part of Port Valdez. Its rocks are on the average a little more metamorphosed, more schistose, and more closely folded than the rocks of the younger Orca series.[a] Interbedded lava flows are nearly or quite absent, though the presence of some greenish schists—probably altered fine-grained tuffs—would indicate that volcanic activity was not entirely absent during the deposition of the Valdez rocks. The Orca series covers much more territory than the Valdez, and is the chief formation of the district. It differs from the Valdez series in the points already mentioned and also in the presence of (1) much black slate, (2) conglomerates, and (3) many interbedded lava flows. The black slate is usually soft and much jointed, is frequently fissile, and in places contains infolded fragments of the graywackes. This slate is well developed in the vicinity of Ellamar. The conglomerates are found at a number of points, and are composed of well-rounded pebbles set in a graywacke or a slate matrix. The lava flows are of a basic nature, were originally mainly diabases and basalts, and have been altered so that they are now greenish in color and are here referred to as greenstones. Many of these flows are ellipsoidal in character, and they are especially common near the base of the Orca series. Associated with the flows are some dikes and probably also some sills, but the intrusive or extrusive nature of some of the greenstones is not always clear in the most folded areas. Characteristic exposures of these greenstones occur on the north side of the entrance to Galena Bay and also on Glacier Island.

In the Orca series a few poorly preserved plant remains have been found, and also some worm tubes, which resemble forms called *Terebellina palachei* Ulrich[b] from Kodiak Island. The Orca series is probably of Mesozoic age. The age of the Valdez series is undetermined.

## MINERAL RESOURCES.

### COPPER DEPOSITS.

The chief ore of the district is chalcopyrite (a sulphide of copper and iron). This is very generally associated with pyrrhotite (magnetic iron pyrites) and, to a less extent, with pyrite (yellow sulphide of iron) and marcasite (white iron pyrites); these iron sulphides probably carry small amounts of copper. Chalcocite was noted in one place, near Orca. Secondary carbonate of copper occurs as a green surface stain; this is usually malachite and rarely azurite. The alteration of the original copper sulphides to form these carbonates is a superficial phenomenon, and they occur at or very near the surface or along cracks within a few feet of the surface. Occasionally small flakes of native copper are found in the upper parts of the veins; this is evidently also a secondary mineral. Oxidation of the iron sulphides has given rise to the usual rusty brown capping (iron hat) to the veins, but this oxidation, except along cracks, extends commonly only a few inches from the surface.

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[a] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 404-409. See also footnote, p. 62 of this bulletin.

[b] Ulrich, E. O., Fossils and age of the Yakutat formation: Harriman Alaska Expedition, vol. 4, New York, 1904, pp. 125-144.

The copper veins now being prospected are mainly along shear zones. These usually occur in the greenstones or in their immediate vicinity. Not uncommonly a shear zone agrees closely with the contact between greenstone and a layer of slate or graywacke. This association of the ore deposits with the greenstones is so pronounced that these igneous rocks can be regarded as the original sources of the copper. The shear zones vary in width from a few inches to several feet—in one case a width of 8 feet being reported. While in a few cases there evidently were along the shear zones open cavities which have been filled with metallic sulphides and quartz, the general conditions indicate that the ore minerals have replaced the country rock, rather than that they were deposited in such cavities.

Most of the prospects show shear zones made up of two rather distinct layers. One is a layer of nearly solid sulphides (chalcopyrite, pyrrhotite, and pyrite), or of these sulphides mixed with some quartz and country rock; the other layer consists of sheared rock, sometimes silicified, with disseminated ore minerals. The sulphide layer may be on one wall of the shear zone, or it may be near the center of the zone with a layer of disseminated ore on either side. This sulphide layer varies considerably in composition in the different prospects, being in some almost solid pyrrhotite and in others chalcopyrite with little pyrrhotite; the variation in composition in any individual sulphide layer is not so marked. In thickness these sulphide layers vary from an inch to, in one case, 8 feet; and any given layer varies in width along both the strike and the dip. Some of the sulphide layers pinch out entirely along the strike and then reappear; thus bodies of ore of lens-shaped cross section occur whose length is several times their greatest thickness. These lenses may also pitch along the direction of the strike. Individual veins have been traced continuously for half a mile or more, and further prospecting will undoubtedly show that some of them can be followed for several miles. In view of the irregularities of the surface and the absence of detailed maps it is difficult to trace individual shear zones except in the few cases where outcrops are frequent. The strikes of the veins vary considerably, but frequently agree rather closely with that of the country rock. The dips of the veins are commonly high, usually between 60° and 90°.

In addition to the shear zones there are some sharply defined veins of small size, and on Knight Island prospecting has been done in a rather massive greenstone which contains disseminated chalcopyrite and pyrrhotite. The two producing mines of the district are in deposits which differ somewhat from the simple shear zones above described.

The ore deposits now known occur, with very few exceptions, in the rocks of the Orca series.

## COPPER MINES.

The Gladhaugh mine is situated at Ellamar on Virgin Bay, on the northeast shore of Prince William Sound. (See fig. 4, p. 79.) The ore body outcrops on the beach between low and high tide marks. It was staked in 1897. During the summer of 1905 this mine shipped about 1,500 tons of copper ore per month. The 100-, 200-, 300-, and 400-foot levels of the mine have been opened up, and work was progressing on the 500-foot level in September, 1905. Since this date it is reported that the ore body has been encountered on this lowest level. The ore on the 200-foot level has a roughly lens-shaped cross section with a length of 190 feet and an extreme width of 80 feet. The direction of the long axis is approximately N. 35° W. The dip of the walls varies from 80° to 90° NE. and there is a pitch of the ore body of about 35° E. The ore body consists of chalcopyrite, pyrite, pyrrhotite, and country rock. Frequently the rock is lacking and then the ore body is practically solid sulphides, with the chalcopyrite in marked amount. The best ore, i. e., that in which the proportion of chalcopyrite is highest, is in general confined to a poorly defined ore shoot which forms the middle of the foot-wall half of the ore body. The country rock is soft black slate, with a few bands of graywacke and black limestone. The strike of the rocks is in general parallel to that of the ore body. Greenstone bowlders, evidently from rock close at hand, occur 150 feet north of the shaft. The black slate is much fissured and crushed and the fragments are commonly slickensided. The ore is in the main massive and not fractured, although there are some small cracks which have been filled with calcite. Search for other ore bodies in the direction of the strike of the one now being mined does not seem to have been made.

The Bonanza mine is situated near the east shore of Latouche Island, within half a mile of tide water, to which a tramway has been built. The ore now being taken out is from the face of a cliff. A working tunnel has been run into the ore body 30 feet below the surface workings, and another tunnel, intended to crosscut the ore at a depth of about 70 feet below the first tunnel, was being run during the summer of 1905. Ore shipments of a few hundred tons monthly were made last summer, and there is good reason to expect that these shipments can be markedly increased in the immediate future. The ore body as first exposed rises in a westward-facing cliff, and from this cliff most of the ore now being shipped is quarried. The upper tunnel just mentioned crosscuts at least part of the ore body, and shows a width of 68 feet of ore which can, with a little sorting, be shipped. Beyond this, to the east, the tunnel cuts about 100 feet of rock which contains stringers of ore. West of the 68 feet of ore just mentioned there is said to be a thickness of about 58 feet of softer ore, which is now covered by the timbering of the tunnel, and about 150 feet farther west is a band of nearly pure pyrrhotite. It is possible that the ore body extends westward to this pyrrhotite band. The length, except for about 200 feet, and the depth, below 30 feet, of the ore body have not been explored. The ore is chalcopyrite. This occurs in brecciated portions of the country rock and in irregular veins, and in places it partially or completely replaces the country rock. This ore deposit lies along a brecciated and sheared zone, and strikes about N. 10° E., dipping 60° W. This is the general strike and dip of the rocks in the vicinity. The main rock in the ore is a very fine-grained, greenish-gray, hard, flinty material. To the east of this is graywacke and quartzite, while to the west there is mainly black slate. No igneous rocks were seen in the immediate vicinity of this mine, but rocks apparently of this nature occur less than a mile to the north, at the Blackbird claim, and also at the north end of Latouche Island.

## COPPER PROSPECTS.

A considerable number of prospectors were at work in Prince William Sound during the summer of 1905, and previous to that time other prospects had been explored which were not being worked last summer. Below are brief descriptions of a number of the prospects. Those selected for description are not necessarily the richest in the district, but are those which, because of their geographical location or other points, are of interest. In none of the places described is machinery used, with the one exception of the workings of the Reynolds-Alaska Development Company, at Boulder Bay. The chief center of interest for prospectors is the vicinity of Copper Mountain. This is a ragged-crested mountain, rising nearly 4,000 feet above sea level and situated about 4 miles southeast of Ellamar. Boulder Bay is at the west base of this mountain and Landlocked Bay at its south base. The rock of Copper Mountain is greenstone, with a small amount of sediments (slate, graywacke, and quartzite).

### SOLOMON GULCH.

Entering the south side of Port Valdez near its east end is a stream which flows through Solomon Gulch. Five miles south from the shore of Port Valdez, and just east of this stream, but still in the bottom of the valley, a prospect has been worked to some slight extent by Valdez miners. A sheared zone of schistose rocks, impregnated more or less with sulphides of copper and iron, is exposed. At the time this locality was visited, in July, prospecting had uncovered a band of schistose and silicified rock striking about east and west and dipping steeply to the north. This belt was, as exposed, 30 feet in width, and consisted of siliceous schist, flinty slate, quartz, pyrite, chalcopyrite, and pyrrhotite. Later in the summer an option on this property was taken by persons interested in a smelter at Hadley, Prince of Wales Island, and their explorations are reported to have shown a width of about 80 feet for this zone of schistose, sulphide-bearing rock. Close by is a mass of altered greenstone, probably existing as a dike. The country rock is schistose slate and graywacke of the Valdez series.

### GALENA BAY.

Considerable prospecting has been done in a depression known as Vesuvius Valley, which extends southward from near the head of Galena Bay to the north flank of Copper Mountain. Work has also been carried on to the east and west. Some stripping has been done and several short tunnels have been run in on veins in the greenstone. These are along shear zones which commonly carry layers of sulphides. The most work has been done on a tunnel which runs eastward under a spur extending to the north from Copper Mountain. This tunnel, dug by the Prince William Sound Mining Company, runs along a clay selvage, which is from an inch to a foot in thickness. Pyrite, pyrrhotite, and chalcopyrite in stringers occur in and near this selvage, and small amounts of these sulphides are disseminated in the wall rock. The tunnel is mainly in greenstone, but a narrow band of black slate is commonly seen along the foot wall of the vein, which strikes in an east-southeast direction and dips 75° NNE. This tunnel is about 300 feet long and was driven to intercept a large shear zone which occurs in the ridge to the east. The tunnel has not yet reached this shear zone, which is about 40 feet wide and contains considerable unsheared rock and locally carries bands and scattered grains of sulphides.

### BOULDER BAY.

Boulder Bay is situated about 4 miles southeast of Ellamar and is so named from the fact that on the beach are a few large bowlders made up of iron and copper sulphides. The largest of these is 20 feet in diameter. Several veins of the usual type have been discovered on both the east and the west shores of this bay. The principal development work has been done by the Reynolds-Alaska Development Company. At the location of the bowlders of iron-copper sulphide a steam engine, an air compressor, and power drills have been installed and a tunnel has been run eastward into the mountain about 300 feet, with the expectation of crosscutting some veins of ore which were known to outcrop higher up on the face of the mountain. In November, 1905, it was reported that a vein carrying a good grade of chalcopyrite was struck at a distance of 400 feet from the mouth of the tunnel. In addition to this tunnel the same company has done other development work on the west slope of Copper Mountain above this tunnel, and other prospectors, working on veins in shear zones in the greenstone have done work to the north of this and also on the west side of Boulder Bay.

### LANDLOCKED BAY.

On the shores of this bay and running up on the south and east flanks of Copper Mountain are a number of rather well-exposed shear zones, mainly in the greenstone. Many of these carry copper and iron sulphides and have attracted much attention from prospectors.

What is known as the Alaska Commercial Company claim is situated on the north shore of Landlocked Bay, and work was done here a few years ago. Recently another company has acquired this property and expects to resume explorations. About 500 feet above the sea, on the face of a cliff, is a shear zone 4 feet in thickness. The strike is N. 68° E. and the dip 75° to 80° N. In this zone is a layer of sulphides (pyrrhotite and chalcopyrite) 2 to 8 inches in thickness. A tunnel has been run in on this vein and the ore taken out was lowered by a wire cable to the dock at the foot of the cliff. Perhaps 70 tons of ore mined a few years ago was shipped in the summer of 1905. Below this vein, 200 feet above the water, a tunnel was run northward into the cliff to intersect the above vein.

This tunnel is 412 feet long and contains practically no ore. The vein was not encountered, unless a barren, narrow shear zone represents this vein where crossed by the tunnel.

Farther east, on the west side of Landlocked Bay, near the head, the Three Man Mining Company has recently conducted explorations. Three tunnels, the longest being 50 feet in length, have been run in along a shear zone containing a layer of fairly solid sulphides. This layer varies from an inch to 2 feet in thickness and has on its hanging-wall side some chalcopyrite disseminated in the sheared country rock. The vein has a general east-west direction and dips toward the north. A small shipment of ore has been made from this place. To the west, on the south slope of Copper Mountain, the same company has other prospects of a similar nature.

In this immediate vicinity other prospectors (especially Messrs. Putz, Steinmetz, Egan, Bourke, and Steele) have been working on similar veins, which show layers of solid sulphides up to 3 feet in thickness. At one of these (Centaur and Standard claims), a mile northeast of the summit of Copper Mountain, the vein has been exposed at intervals for a distance of 400 feet. Here there is a layer of sulphides (chalcopyrite and pyrrhotite) from 2 inches to 3 feet in thickness. The shear zone of this layer averages 15 to 18 inches in width and contains a little ore. The strike of the vein is N. 48° E. and the dip is from 80° to 90° E.

### ORCA.

A mile and a half southwest of Orca is a small sand spit known as Flemming Spit. Two streams enter the bay near this point. On the westerly and larger of these streams, three-fourths of a mile from its mouth and about 500 feet above the sea, there are two small prospect holes. The country rock is a much crushed, reddish, amygdaloidal basalt, with irregular stringers of epidotized rock. These stringers are of all widths up to 2 feet, and while some of them have a vein-like form, striking in an east-northeast direction and standing vertically, most of them show no common direction of elongation and pinch out in short distances. With the epidote is quartz. The ore, which is chalcocite, occurs associated with and in the epidote-quartz stringers, although in places it is associated with the non-epidotized country rock. No vein of ore can be said to exist here—only irregular masses of small size. Some native copper has been reported from this locality. The country rock, its alteration to epidote-quartz masses, and the occurrence of copper ore with these masses all resemble conditions in parts of the Lake Superior copper district, except that in the latter district the ore is native copper.

### GLACIER ISLAND.

Glacier Island is composed almost exclusively of greenstones of the Orca series. There are several prospects on and near the east end of the island and also on the eastern shore of the bay which indents the southern coast of the island. These prospects are (1) in veins running along shear zones, and are closely similar to those about Copper Mountain, (2) in irregular stringers in the greenstones, and (3) in quartz veins. One of the last type occurs just southwest of a small lake less than a mile from the east end of the island. Here a short tunnel has been run in to cut a vein 10 feet in width. The strike is N. 23° E. and the dip 70° N. Along the foot wall of the vein is a 2-inch seam of clay gouge. The vein material is mainly quartz and fragments of country rock (greenstone), with small amounts of chalcopyrite, pyrite, and apparently marcasite.

### KNIGHT ISLAND.

In a few places along the eastern shore of Knight Island a small amount of prospecting has been done. One of these points is about 4 miles north of the south end of the island and at the north side of the entrance to a small bay. There are two tunnels here, running northward from the shore. The western tunnel is about 150 feet long and in its last 30 feet passes out of the rock into the glacial drift. The ore is chalcopyrite, which occurs in small stringers in greenstone. The eastern tunnel is 25 feet long and runs along a quartz-filled shear zone, which contains a little chalcopyrite. About a mile south of this locality is another claim, on which there is a vein 8 to 15 inches in width. The country rock is here gray quartzite, but greenstone is near at hand. The vein consists of rather solid sulphides (pyrrhotite and chalcopyrite), with some quartz and country rock. Practically no exploratory work has been done at this point.

About two-thirds of a mile northeast from the northeasternmost arm of Mummy Bay (which indents the southwestern shore of Knight Island), and about 1,300 feet above the water, close to the divide between this bay and the small bay in which are the prospects above mentioned, is another prospect in a shear zone in greenstone. This zone is 1 to 5 feet wide, and the ore is in irregular stringers and consists of chalcopyrite, pyrite, and a little pyrrhotite. This zone carrying ore is exposed at two points. The general situation here is closely similar to that in the vicinity of Copper Mountain. A mile north of the west end of Mummy Bay is another prospect, in which there is exposed a lens of ore 7 feet long and 2 feet wide at the surface. The ore is fairly solid pyrrhotite, pyrite, and chalcopyrite. The country rock, which is here a rather coarse-grained dioritic greenstone, contains more or less disseminated sulphides (pyrrhotite with a little chalcopyrite), and in one irregular pegmatite vein there is more of this disseminated ore.

Near the head of Drier Bay, which is near the center of the west side of Knight Island, work has been done on a prospect near the divide. This was examined by Sidney Paige, who reports as follows:

> A lens of ore approximately 30 feet wide and 40 feet high, consisting of chalcopyrite and pyrrhotite in greenstone (diabase), occurs exposed in the face of a bluff 975 feet above the sea and 2,800 feet from the beach. The lens is of nearly solid ore and rather uniform in character. It cuts slightly across the general and dominant joint system of the country rock, which is very similar to the rock carrying the ore. The strike along the ore body—that is, its length—is S. 72° E., while the cleavage in the country rock is N. 80° E. to N. 17° W. Slightly above and to the northwest of this ore body occurs a similar but smaller lens, which strikes N. 7° W. and dips 62° N. It measures about 9 feet across the strike and is approximately 25 feet long. From all indications it pinches at both ends. Its depth is unknown.
>
> Of the country rocks in this vicinity there are three types—very fine grained, hard, nearly black, basic rock; a coarse-grained, black, basic diabase, and a porphyrytic diabase, the latter being the freshest of the lot.
>
> The ores seem to be a replacement of the country rock. The fact that the bodies occur as lenses may be suggestive. The strata seem to bend around the second and smaller lens in a manner to suggest a possible widening of the space between the walls.

### LATOUCHE ISLAND.

Both to the northeast and the southwest of the Bonanza mine prospecting has been done at a few points, apparently along the strike of the ore body at that mine. In several instances a vein of nearly solid sulphide ore, corresponding to that at the west side of the mine, has been encountered. The most extensive prospecting has been done on the Blackbird claim, about half a mile northeast of the Bonanza mine. Here there has been a considerable amount of trenching and a few shallow test pits have been sunk. These workings show that the ore, which is in considerable amount, occurs both to the east and the west of the marked vein of solid sulphide. The ore (chalcopyrite) occurs disseminated through the rocks, which are here mainly graywackes and quartzites. It also occurs in rather solid veins, and a soft schistose rock which contains talc and also small cubes of pyrite is associated with it. This rock is probably an altered igneous rock. It is understood that the property has recently changed hands and that the new owners will begin active operations in the immediate future.

About 4 miles southwest of the Bonanza mine work has been done on what is known as the Blue Fox claim. Here apparently the same band of solid sulphide, which is here mainly pyrite, has been encountered, and a tunnel 50 feet in length has been run along this sulphide vein. Openings have been made also to the west, showing some ore. Crosscutting both east and west of the sulphide vein would probably show up more ore than is now in view. About half a mile northeast of this point is the Duchess claim, on which a branching tunnel 300 feet in length has been run.

### GOLD AND SILVER.

In a number of places throughout the district are quartz veins which carry small amounts of iron and copper sulphides and which have been prospected for gold and silver. Three of these veins, which were reported to show considerable values in gold, were examined—one on the north flank of Copper Mountain, one in the eastern part of Glacier Island, and one on the point between Landlocked Bay and Port Fidalgo. Assays have been made from two of these veins; one assay was from the decomposed upper part and the other from the solid vein about 15 feet below the surface. The assay reports show only traces of gold and a fraction of an ounce of silver per ton. While these assay results are not encouraging, at the same time it is quite possible that quartz veins may be found about the sound which will carry gold in economic quantities.

In the copper veins, gold and silver are almost invariably present in small amounts, and commonly gold is found in the copper ores which have been shipped from both mines, in amounts running from $1 to $5 per ton. The silver content of these copper veins is commonly less than $1 per ton.

In 1900 some gold-bearing veins were reported from near Alaganik, on the Copper River delta, [a] but no recent work seems to have been done in this locality.

Some prospecting for placer gold has been done about the shores of Prince William Sound, but work of this sort was not carried on during the summer of 1905. Small amounts of placer gold have been reported from near the mouths of Gold Creek and Mineral Creek, which enter the north side of Port Valdez, and also about the streams entering the bay at the foot of Canyon Creek Glacier. A few years ago the gravels in Solomon Gulch, south of Valdez, were explored for gold, but evidently without success.

### NICKEL.

At two points on the shores of Prince William Sound there has been prospecting for nickel during the past year. One occurrence is in small stringers along the south side of Port Valdez, and the other is near the mouth of Miners River, on the east side of Unakwik Bay. At the latter place the owners of the property were not present when the Survey party visited it. A tunnel about 8 feet long was found on the north side of the bay into which Miners River enters. The country rock is diorite, carrying disseminated pyrrhotite. The vein, if it can be so called, is a zone in the diorite impregnated with this iron sulphide and has no sharply defined walls. This sulphide-bearing rock is 10 or more feet in width, and above the tunnel, which is at the water's edge, a zone of iron-stained rock, perhaps 20 feet in width, can be seen running up the cliff. Here also there are in the diorite some pegmatitic veins which also carry pyrrhotite. These veins resemble those described from north of Mummy Bay on Knight Island. They are from one-fourth inch to 2 inches in width and are not sharply defined. There are also in the dioritic country rock small fractures filled with quartz, but these do not, at least so far as seen, carry the iron sulphide. It was thought that the pyrrhotite carried considerable values of nickel and also of cobalt. Selected samples of the best ore which could be found at this particular point were assayed and the results show neither cobalt nor nickel.

### LEAD AND ZINC.

A few veins containing small amounts of galena (sulphide of lead) and sphalerite (sulphide of zinc) have been seen, but in no case did they contain sufficient quantities of these minerals to encourage prospecting for lead and zinc.

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[a] Schrader, F. C., and Spencer, A. C., The Geology and Mineral Resources of a Portion of the Copper River District, Alaska (a special publication of the U. S. Geol. Survey), 1901, p. 90.

## CONCLUSIONS.

Two mines on Prince William Sound have demonstrated that copper ore of good grade occurs in this district and that it can be produced at a profit, notwithstanding the fact that the ore is shipped, at an expense of $2.50 to $3 per ton, to Tacoma, Wash., before it is smelted. Up to the present time nearly the entire output has been from the Gladhaugh mine. At the Bonanza mine existing developments warrant the prediction that there will be an early increase in production and that a large body of ore will be found available. None of the prospects, as developed in the summer of 1905, showed indications of as large an ore body as is known at either of the two mines.

Though very definite conclusions can not yet be formulated without more thorough study of the data at hand, certain of the more important facts throwing light on the character of the deposits may be stated.

Erosion in very recent time has been general throughout the Prince William Sound region, so that no considerable secondary concentration of ores exists. The ores of possible commercial importance have all the characteristics of primary deposits and are a phase of a general sulphide deposition along certain channels or zones. In general there is no reason to expect that stringers of ore on the surface will develop in depth to payable veins or that veins of considerable width at the surface will continue with unvaried dimensions and richness to great depths. On the contrary, it is known that ore bodies pinch out in individual cases, and, on the whole, irregularity of form is to be expected. Developments of prospects should be confined to the following of ore. Running long crosscuts to catch stringers or veins in depth is bad practice, since experience has shown that the continuation of the deposits is by no means assured.

Throughout the district much of the development work has been misdirected and nowhere except on Latouche Island and at Virgin Bay have excavations gone far enough to definitely prove the presence of workable ore bodies. However, at a number of prospects the copper and gold contents of the ore are sufficiently high for profitable mining and these places are worthy of further prospecting. These facts, coupled with the location of many of the veins at or very close to tide water and the present demand for ores of this character for furnace mixtures, give reason to expect an increase of copper mining outside of the two mines already in operation. Should the future see the establishment on Prince William Sound of plants for smelting the copper ores of the Copper River district, for which purpose the coal of the Bering River or Matanuska field could be utilized, the prospect for mining on the sound would be still brighter.

# PRELIMINARY STATEMENT ON THE MATANUSKA COAL FIELD.

By G. C. Martin.

## INTRODUCTION.

The region described in this paper extends in a northeasterly direction from the northern shore of Knik Arm, which is the northernmost branch of Cook Inlet, in approximately latitude 61° 30′, longitude 149° 30′, to latitude 61° 50′, longitude 148°. (See map, Pl. II.) It is thus about 80 miles long, from northeast to southwest, and from 5 to 10 miles wide.

The writer spent about three weeks in this field in the summer of 1905 and visited the region immediately adjacent to Matanuska River from Knik Arm nearly to the mouth of Hicks Creek. The following pages contain an abstract of the economic results of this investigation. A more complete report is in press.[a]

The Matanuska rises in the southwest corner of the interior plateau known as the Copper River basin, in latitude 62° N., longitude 147° W. It flows in a westerly and southwesterly direction for an air-line distance of about 100 miles, and empties into Knik Arm, the northernmost arm of Cook Inlet. The tributaries include Caribou, Hicks, Chickaloon, Kings, Granite, and Tsadaka[b] creeks, on the north side, and Matanuska Glacier, a large number of small creeks (mostly unnamed), and Knik River on the south side.

Matanuska River occupies a meandering gorge within a valley which is from 5 to 10 miles wide. The Talkeetna Mountains are on the north, and the western extension of the Chugach Mountains is on the south. The fronts of both these mountain masses lie in fairly distinct lines parallel to the general course of the river. The Talkeetna Mountains seem to be made up for the most part of ridges parallel to the river, while the Chugach Mountains consist chiefly of less regular masses. The general maximum elevation of each is, roughly, 5,000 to 6,000 feet. The hills within the valley have elevations of from 1,000 to 3,000 feet and increase to the east. The valley bottom rises at a gradually increasing rate and attains an elevation of about 3,000 feet at the source of the main stream.

The flats at the head of Cook Inlet are densely timbered with a small but fairly uniform growth of cottonwood, spruce, quaking aspen, and birch (the latter predominating), with a sparse undergrowth of alder, willow, currant, and huckleberry bushes. Scattered through the forests are broad meadows of excellent grass. A similar growth of timber extends throughout the valley of the Matanuska and its tributaries up to an elevation of 2,000 feet. From this point to an elevation of about 2,500 feet the timber becomes thinner and at a maximum elevation of about 2,800 feet it finally disappears. The spruce is considered of good quality, though small. Some of it will square 12 inches, considerable of it 8 inches, and most of it 6 inches. There will probably be abundant timber for mining and local building purposes, especially as the supply will not be drawn on for fuel.

The post-office and shipping port for the entire region is Knik, which is at the head of steamboat navigation on Knik Arm. Knik is reached by an ocean voyage of seven to twelve days from Seattle to Seldovia and one or two days by local steamers on Cook Inlet. There is a good horse trail from Knik to the coal field. It requires a day or a day and a half to go from Knik to Tsadaka Creek, and a day from Tsadaka Creek to Chickaloon Creek. Supplies can be purchased at Knik, where there are two stores, and natives can usually be secured there. Horses can sometimes be hired at Knik, but it is not safe to depend on them unless arranged for in advance.

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[a] Martin, G. C., A reconnaissance of the Matanuska coal field: Bull. U. S. Geol. Survey No. 289.

[b] Generally known as Moose Creek.

## OUTLINE OF THE GEOLOGY.

The rocks in that part of the Matanuska Valley which was visited by the writer consist of coal-bearing sediments, partly Mesozoic and partly Tertiary, two distinct horizons apparently being represented; Jurassic rocks, known only from stream bowlders; a large number and considerable variety of dikes and volcanic flows, granites and other coarse crystalline rocks bordering the valley on either side; and a large amount and broad extent of very young gravels.

### COARSE CRYSTALLINE ROCKS.

These rocks occur in the high mountains on either side of the Matanuska Valley. They are known to the writer only from the stream bowlders, from the reports of prospectors, and from the appearance of the mountains as seen from a distance. They appear to consist chiefly of granite and diorite, although a variety of other rocks, including greenstone, is present.

### MESOZOIC ROCKS.

Bowlders of dark, hard sandstone of very different lithologic character from anything seen in place by the writer were found in the bed of Chickaloon Creek. They contain many specimens of *Aucella* of an upper Jurassic species. The presence of upper Jurassic rocks in the Talkeetna Mountains is thus established. The bowlders were much worn and not abundant, indicating that the outcrops of these beds are at a considerable distance from the Matanuska.

A sharp ridge, about 5,500 feet high, borders the north side of the Matanuska Valley between Boulder and Hicks creeks. It is part of the southern front of the Talkeetna Mountains. This ridge consists chiefly of graywacke, with numerous calcareous concretions and beds of anthracite coal. About midway on this ridge a very few fragmentary fossils were obtained, which indicate an age between middle Jurassic and upper Cretaceous.

Rocks of possibly the same age were seen by Mendenhall[a] near the headwaters of Bubb and Caribou creeks, about 25 miles northeast of the locality just mentioned.

### TERTIARY ROCKS

The rocks in the valley of the Matanuska from Chickaloon Creek to Tsadaka Creek consist chiefly of shale and sandstone, with many coal and lignite beds and at least one bed of massive conglomerate. The conglomerate belongs near the top of these rocks, which altogether can not be less than 3,000 or 4,000 feet thick.

There is little doubt that part, at least, of these beds are of the same age as the coal-bearing rocks at Homer, on Cook Inlet, which are generally considered to belong to the middle Tertiary (Oligocene).

### GRAVELS.

The valley of the Matanuska and its tributaries from the head of Cook Inlet to a point somewhat above Chickaloon Creek is covered with thick deposits of coarse gravels which occur in a series of benches or terraces, often concealing all of the hard rocks. The gravels are composed of bowlders of diverse character and vary in size from fine sandstone to material a foot or more in diameter. It is reported that they carry very small amounts of gold, but, so far as is now known, not enough to be of value even where the gravels have been reworked by the streams that are cutting through them.

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[a] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 265-340.

### DIKE ROCKS.

There are numerous dikes of diabase throughout a large part of the Matanuska Valley. They are more frequent and larger toward the upper end of the valley and are also more numerous wherever folding and faulting is strongest. The coal-bearing rocks at many places are cut by numerous small dikes and sills of diabase, which, wherever it has come into close proximity to the coal, has altered it to a dense, hard coke. Dikes of this general character are common throughout the greater part of the coal field and always have this effect on the coal.

A large intrusive mass of porphyritic rock occupies the mountain north of Kings Creek and immediately west of the trail. At the upper bridge over Kings Creek, 3 miles above the locality just mentioned, is a sheet of porphyritic rock apparently interbedded in the Tertiary coal-bearing rocks. The thickness is at least 50 feet.

### STRUCTURE.

The Matanuska Valley is a zone of soft Tertiary shales and sandstones, with some conglomerates and igneous rocks, included within two masses of plutonic rocks associated with Mesozoic sediments. The Tertiary belt is from 7 to 8 miles wide and has fairly straight and parallel boundaries which form the topographic limits of the greater valley within which the Matanuska flows.

The Tertiary rocks are involved in a system of combined folds and faults. The folds are open and the faults often cut the axes of the folds. The general strike is parallel to the course of the Matanuska, being N. 60° E. below Chickaloon Creek and N. 75° to 90° W. above Chickaloon Creek. There are, apparently, subordinate folds parallel to the course of Kings, Eska, and Tsadaka creeks.

The Mesozoic anthracite-bearing rocks east of Boulder Creek are more closely folded than the Tertiary rocks of the center of the valley. They are separated from the latter by a fault or system of faults parallel to the axes of folding.

## COAL.

### AREAL DISTRIBUTION.

Coal outcrops have been seen by the writer on Tsadaka, Eska, Kings, and its tributaries, Chickaloon, and Coal creeks, and on the small creeks heading in the Talkeetna Mountains between Boulder and Hicks creeks, as well as in the banks of Matanuska River, about 3 miles above the mouth of Chickaloon Creek. (See fig. 5.) They have also been reported from Boulder, Hicks, and Caribou creeks, from a creek on the south side of the Matanuska, 9 miles above Coal Creek, and from Little Sushitna River.

The extent of the area underlain by coal is not very definitely known. There are at least 70 square miles of coal in the valley of the Matanuska and its tributaries from Tsadaka Creek to Hicks Creek, inclusive. This is a conservative estimate, based on outcrops actually known to the writer. It is possible that there is a larger area than this, but it seems certain from present knowledge that the coal area in the region indicated above can not in any case exceed 300 square miles, except by further extensions of this field or neighboring fields outside the region visited by the writer, which might increase the area to limits which we have no means at present of knowing.

### POSITION AND SECTIONS OF THE COAL.

There are at least two distinct kinds of coal in this region, occurring at two widely separated geologic horizons. One is the anthracite coal, which is Mesozoic, and the other includes various grades of bituminous coal, which are of Tertiary age.

### ANTHRACITE.

The Mesozoic coal, as stated above, is apparently all anthracite. It was seen by the writer only along the flanks of the Talkeetna Mountains, between Boulder and Hicks creeks. This coal has the ordinary physical characteristics of most good coal of this kind. It is heavy, firm, hard, and not much fractured, even at the surface, and has a high luster. Pyrite was not noticed. The seams are not much broken by small partings of shale and bone.

Two sections were measured. On the south bank of Purinton Creek, at an elevation of 3,410 feet, an exposure was measured which showed 38 feet of clean, solid coal, both roof and floor being concealed. (See analysis No. 1, p. 98.) At this point the strike is N. 40° E. (magnetic) and the dip is 10° NW., or into the mountain. The rocks in the vicinity are chiefly graywacke and sandstone and show considerable variation of strike and dip. A

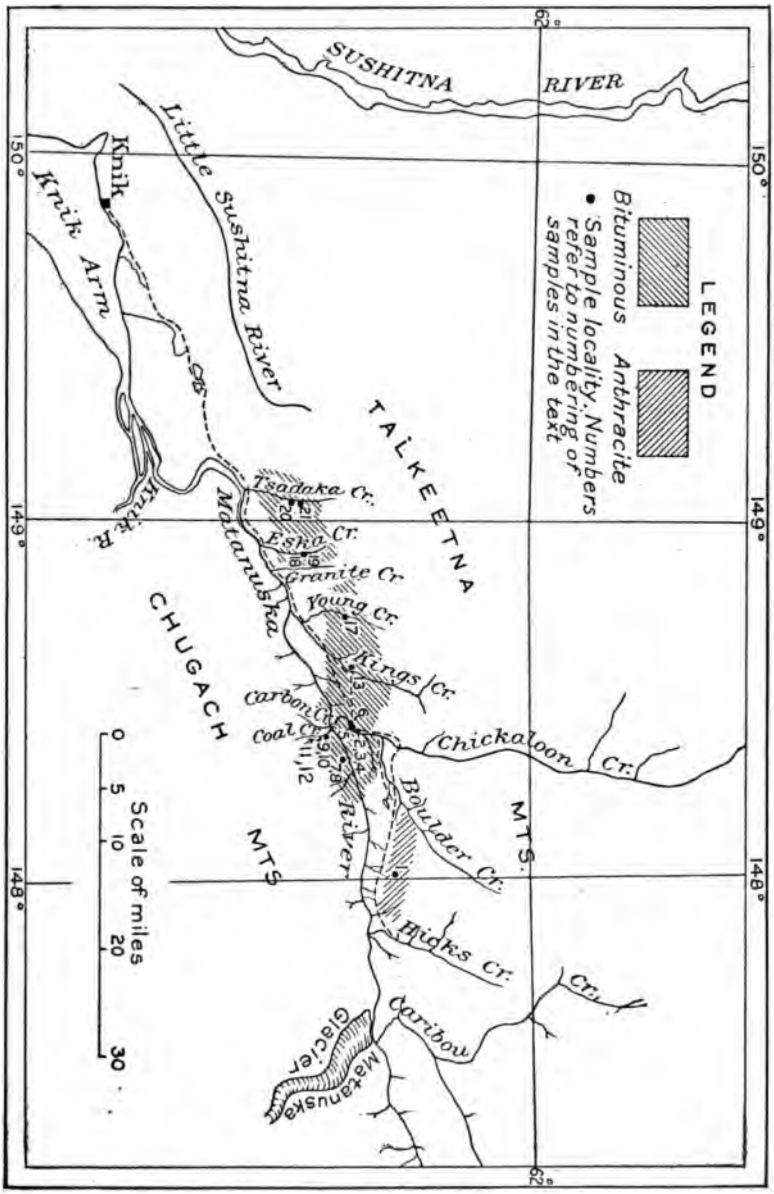

FIG. 5.—Sketch map of Matanuska Valley, showing coal field, so far as known.

short distance downstream is a good-sized mass of diabase occupying the axis of an anticline, which is in other places broken by a fault. The anthracite is probably restricted to a zone along the face of and in the mountains, which is cut off from the valley plateau by a fault following the base of the mountains. Black streaks which are probably coal could be seen high up on the face of the mountain and could be followed by the eye for several miles. About 1 mile northeast of the locality just described, at an elevation of about 3,460 feet, a coal section gave the following measurements:

*Section of coal on slope of Talkeetna Mountains.*

| | Feet. |
|---|---|
| Flaggy sandstone. | |
| Coal and shale | 3 |
| Coal | 7 |
| Shale | 4 |
| Coal | 1 |
| Shale | 3 |
| Coal | 2 |
| Shale | 2 |
| Coal | 7 |
| | 29 |

Strike N. 60° E., dip 55° SE. The general strike along the side of the mountain is N. 75° E. (magnetic). The area of anthracite was not estimated by the writer, and the amount available for economical mining and shipment may possibly not be sufficient to justify the necessary expenditures. On the other hand, the field may, as has been reported by some, extend far beyond the areas visited.

### BITUMINOUS.

#### EASTERN FIELD.

The coal included under this heading, which is probably all of Tertiary age, was seen on both sides of the Matanuska in the vicinity of Chickaloon Creek and in the valleys of Chickaloon and Kings creeks. Coal has been reported for a considerable distance along the linear extension of this belt to the east, but the amount and quality of the coal are not known.

The coal in this area all possesses about the same physical characteristics, and, as will be seen in a subsequent chapter, the variation in chemical composition is not great and supports this grouping. This coal has the ordinary properties of most bituminous coal. It is soft and fragile, but often without any well-defined planes of fracture. It burns with a moderate amount of smoke and possesses distinct caking properties. The seams generally contain a large amount of impurities, both in the form of thick partings of shale and as thin bands of shale and bone. Many of these can not be separated in mining. The coal is soft and friable, and much of it will not stand severe handling without crushing. Pyrite is present, both as balls and as scales, but not abundant. The friable character of the coal is not a serious detriment when it is considered that much of it will probably have to be crushed and washed (especially for coke making) and that the coal, when used for steam or heating, will cake as soon as put in the furnace, so that there will consequently be little or no loss through the grates.

The following sections were obtained on the south side of the Matanuska near the mouth of Chickaloon Creek:

*Section of coal beds on south bank of Matanuska River, 3 miles above the mouth of Chickaloon Creek.*

| | Ft. | in. |
|---|---|---|
| Gray shale | 10 | |
| Coal | | 6 |
| Shale | | 1 |
| Coal[a] | 7 | |
| Gray shale with ironstone bands | 42 | |
| Coal | | 6 |
| Shale | 1 | 6 |
| Coal | 5 | |

---

[a] Included in samples No. 7 and No. 8, p. 98.

| | Ft. | in. |
|---|---|---|
| Gray shale | 7 | |
| Coal | | 6 |
| Shale | 4 | 6 |
| Coal | | 8 |
| Shale | | 1 |
| Coal | 5 | 8 |
| Soft gray shale | 20 | |
| Concealed to river. | | |

Strike N. 36° E. (magnetic), dip 44° SE.

*Section on north bank of Coal Creek, elevation 1,010 feet.*

| | Ft. | in. |
|---|---|---|
| Soft dark shale | 10 | |
| Coal [a] | 2 | 2 |
| Parting. | | |
| Coal [a] | 1 | 5 |
| Sandstone | | 2-6 |
| Coal [a] | 1 | |
| Soft shale | 10+ | |

Strike N. 64° E., dip 70° SE.

*Section on north bank of Coal Creek, 500 feet upstream from the last.*

| | Ft. | in |
|---|---|---|
| Intrusive sheet and coke | 12 | |
| Coke | 5 | |
| Intrusive sheet with coke | 14 | |
| Shale | 10 | |
| Coal [b] | 6 | 3 |
| Shale | | 2 |
| Coal [b] | | 6 |
| Shale | | 11 |
| Coal | | 9 |
| Soft shale floor. | | |

Strike and dip as above.

*Section on Coal Creek, one-half mile above lower coal.*

| | Feet. |
|---|---|
| Coal | 6± |

Strike N. 60° E., dip 55° NW.

The following sections were measured on Chickaloon Creek:

*Section near Watson's camp, Chickaloon Creek.*

| | Ft. | in. |
|---|---|---|
| Shale | 10 | |
| Coal | 1 | 4 |
| Shale | | 6 |
| Bone | | 6 |
| Coal [c] | 7 | |
| Shale with coal streaks | 4 | 6 |

Strike N. 72° E., dip 72°, 75°, 83° NW.

*Section in tunnel No. 2, Chickaloon Creek.*

| | Ft. | in. |
|---|---|---|
| Shale | 20 | |
| Coal | 6 | |
| Hard shale | 17 | 6 |
| Bone [d] | | 10 |
| Coal [d] [e] | | 2 |
| Coal with some bone [d] | 2 | 5 |
| Coal [d] [e] | 1 | 10 |

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[a] Included in samples No. 9 and No. 10, p. 98.

[b] Included in samples No. 11 and No. 12, p. 98.

[c] Included in sample No. 5, p. 98.

[d] Included in sample No. 2, p. 98.

[e] Included in sample No. 3, p. 98.

| | Ft. | in. |
|---|---|---|
| Shale and bone | 2 | 8 |
| Bony coal[a] | | 6 |
| Coal[a][b] | | 11 |
| Bone[a] | 1 | 11 |
| Coal[a][b] | 2 | 4 |
| Bone[a] | | 5 |
| Coal[a][b] | | 8 |
| Bone[a] | | 5 |
| Hard shale floor. | | |

Dip almost vertical toward mouth of tunnel.

It is reported by the owner of the property that a 7½ foot seam was discovered, after the writer left the region, at a distance of 22 feet farther in.

*Section in tunnel No. 5, Chickaloon Creek.*

| | Ft. | in. |
|---|---|---|
| Shale | 10 | |
| Coal[c] | 1 | 8 |
| Shale | | 6 |
| Bony coal | 1 | 8 |
| Shale | | 10 |
| Coal[c] | 6 | 2 |
| Shale | 28 | |

Strike N. 62° E., dip 51° N-E.

The coal seams exposed or opened on Kings Creek gave the following sections:

*Section in opening on west bank of Kings Creek at upper bridge.*

| | Ft. | in. |
|---|---|---|
| Coal[d] | 2 | 5 |
| Sandstone | | 2 |
| Coal[d] | 1 | 4 |
| Shale | | 1 |
| Coal[d] | 1 | 5 |
| Sandstone | | 1 |
| Bony coal[d] | 1 | |
| Sandstone | | 1 |
| Coal[d] | 3 | 4 |

Strike N. 42° W. (magnetic), dip 40° NE.

*Section in tunnel on east bank of Kings Creek 100 yards above upper bridge.*

| | Ft. | in. |
|---|---|---|
| Dense impure coke | 5 | |
| Bony shale | 1 | |
| Coal | 1 | |
| Shale | | 1 |
| Coal | | 8 |
| Bone | | 1 |
| Coal | 1 | 2 |
| Bony coal | | 9 |
| Coal | 2 | 6 |
| Hard shale. | | |
| | 12 | 3 |

Strike N. 18° E. (magnetic), dip 18° SE.

*Section in open cut 10 feet south of last opening.*

| | Ft. | in. |
|---|---|---|
| Coal (no cover) | 3 | |
| Shale | | 2 |
| Coal | 1 | 2 |
| Soft impure coal | | 2 |
| Coal | 1 | 8 |
| Shale | | 3 |
| Coal | | 3 |
| Shale and coal | | 7 |
| Coal | 2 | 8 |
| Hard shale floor. | | |
| | 9 | 11 |

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[a] Included in sample No. 2, p. 98.

[b] Included in sample No. 3, p. 98.

[c] Included in sample No. 6, p. 98.

[d] Included in samples No. 13 and No. 14, p. 98.

The following seam is exposed on Young Creek at an elevation of 1,585 feet:

*Section on west bank of Young Creek.*

| | Ft. | in. |
|---|---|---|
| Shale | 10 | |
| Sandstone | 2 | |
| Shale | 4 | |
| Sandstone | 1 | |
| Shale | 4 | |
| Coal[a] | 1 | |
| Shale | 15 | |
| Coal | | 6 |
| Shale with sandstone bands | 15 | |
| Sandstone | 1 | |
| Shale | 10 | |

Strike N. 15° E. (magnetic), dip 20° NW.

### WESTERN FIELD.

The coal in the west end of the bituminous belt as seen on Eska and Tsadaka Creeks has been considered locally as lignite. The analyses, however, indicate that it is in all probability a low-grade bituminous coal. This conclusion is supported by the fact that the coal does not differ greatly in physical properties from that on Chickaloon and Kings creeks. The seams have about the same characteristics as those o the east. Much of the coal is bright and hard, but there are frequently dull bands with a shaly fracture which resemble a very coaly bone. The appearance of these may be due in part to impurities, but is possibly also caused in part by less complete carbonization. There is little doubt that the coal is of Tertiary age, and the beds are presumably the stratigraphic equivalents of those to the east.

*Section on west bank of Eska Creek, elevation 875 feet.*

| | Ft. | in. |
|---|---|---|
| Shale and sandstone | 10 | |
| Coal[b] | 1 | 3 |
| Shale | | 1 |
| Coal[b] | 1 | 4 |
| Shale | | 1 |
| Coal (bony) | 1 | 3 |
| Shale | | ½ |
| Bony coal | 1 | 1 |
| Shale | | 1 |
| Coal with some shale and bone | 2 | 6 |
| Shale | | 6 |
| Coaly shale | 2 | |

Strike N. 30° E. (magnetic), dip 44° NW.

*Section on west bank of Eska Creek about 300 feet farther up.*

| | Ft. | in. |
|---|---|---|
| Shale | | 2 |
| Coal[c] | 3 | 3 |
| Shale | | 3 |
| Coal | | 11 |
| Shale | | 5 |
| Coal | | 6 |
| Shale | | 6 |
| Coal | | 4 |
| Shale | | 1 |
| Coal | | 9 |
| Soft black shale. | | |

Dip NW.

*Section on Eska Creek about 600 feet above lower section.*

| | Ft. | in. |
|---|---|---|
| Shale and sandstone. | | |
| Coal | 2 | 6 |
| Dirty coal | 1+ | |

Dip 32° SE.

---

[a] Included in sample No. 17, p. 98. [b] Included in sample No. 18, p. 99. [c] Included in sample No. 19, p. 99.

*Section in bluff on west bank of Eska Creek, elevation 1,030 feet.*

| | Ft. | in. |
|---|---|---|
| Sandstone | 15 | |
| Coal | 2 | |
| Shale | 15 | |
| Coal | 3 | |
| Shale | 3 | |
| Coal | 3 | |
| Concretionary shale | 6 | |
| Black shale | 5 | |
| Coaly shale | 1 | |
| Shaly coal | | 6 |
| Coal | | 9 |
| Shale with some coal | | 8 |
| Coal | 2 | 1 |
| Shale | 1 | |
| Coal | 1 | 4 |
| Shale | 1 | |
| Coal | 1 | |
| Shale | 2 | |
| Coal | 1 | |
| Shale | 12 | |
| Coal | 1 | |
| Shale | 2 | |
| Coal | 1 | |
| Shale | 10 | |

Strike N. 40° W. (magnetic), dip 40° SW.

A fault cuts this bluff. The section was measured above it. Below it the strike is northeast, and the dip southeast.

The following measurements were made on Tsadaka Creek:

*Section of coal near upper end of Tsadaka Creek gorge, elevation 700 feet.*

| | Ft. | in. |
|---|---|---|
| Fissile black shale | 1 | |
| Carbonaceous shale | | 6 |
| Sandstone | | 2 |
| Coal | | 2 |
| Sandstone | | 1 |
| Bright coal[a] | 2 | 4 |
| Shale | | 6 |
| Bright coal[a] | 2 | |
| Dull coal[a] | 1 | 2 |
| Shale | | 4 |
| Dull coal | 1 | 6 |
| Shale | 1 | |
| Massive sandstone | 6 | |

Strike N. 20° W., dip 24° NE.

*Section on east bank of Tsadaka Creek, about 100 yards below upper cabin, elevation 780 feet.*

| | Ft. | in. |
|---|---|---|
| Coal with hard ferruginous inclusions | 3 | |
| Shale | 2 | |
| Coal (bright)[b] | 4 | 6 |
| Shale | | 2 |
| Coal (bright and hard)[b] | 7 | |
| Soft shaly coal | 1 | |
| Soft shale with abundant iron balls | 80± | |
| Massive sandstone | 10± | |

Strike N. 50° E., dip 43° NW.

A westward extension of the coal is reported on Little Sushitna River, but that region was not visited by the writer. The coal is said to occur in thin beds and to be lignite, but it is not known whether it is a true lignite or a low-grade bituminous coal like that on Eska and Tsadaka creeks.

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[a] Included in sample No. 20, p. 99.

[b] Included in sample No. 21, p. 99.

## CHARACTER OF THE COAL.

### CHEMICAL AND CALORIMETRIC TESTS.

The samples collected by the writer were all (with the exception of No. 3) taken in a uniform manner. They were obtained by making a cut across a fresh face of the coal from roof to floor, cutting down only the coal which would probably be loaded, and leaving out such impurities as could be separated in the ordinary practices of actual mining. The parts of each seam which went into the sample are indicated in the local sections. No. 3 was taken from only the best parts of the seam (see p. 93), and impurities were rejected which could be separated in practice only by very careful treatment, such as in "screened and hand picked" coal or possibly by some mechanical process or by washing. The object was to show, by a comparison of analyses No. 3 and No. 2, what could be gained by such treatment.

The other analyses were gathered from a variety of sources. Nos. 4, 8, 10, 12, and 14 are duplicate analyses of samples taken by the writer. The others are of varied character, some being fair representations of the seams and some random selections of samples of the best coal.

The anthracite coal is represented by a single analysis (No. 1), which shows it (so far as this one outcrop is concerned) to compare not unfavorably with some of the Pennsylvania anthracite.

*Comparative analyses of Matanuska and Pennsylvania anthracite.*

| Coal. | Moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Fuel ratio. |
|---|---|---|---|---|---|---|
| Matanuska | 2.55 | 7.08 | 84.32 | 6.05 | 0.57 | 11.91 |
| Pennsylvania (average of 9 samples) [a] | 3.39 | 3.81 | 83.79 | 8.42 | .59 | 22.33 |

[a] Ashburner, C. A., Ann. Rept. Geol. Survey Pennsylvania, 1885, p. 313.

The coals represented by analyses 2 to 17 are near the border line between semibituminous[a] steam coals and bituminous coking coals. They are rather high in ash, but are otherwise of good quality. Analyses 5 and 6 bring the average abnormally high, but even otherwise most of the seams are so impure that mechanical separators or washing should be used to remove part of the impurities. The purer of these coals corresponds very closely to the Crows Nest Pass (British Columbia) coal,[b] which is the standard coking coal of western North America, and approximately to some of the coking coal of the East.

The lower-grade bituminous coal on Eska and Tsadaka creeks, which the analyses show to be intermediate between first-class bituminous coal and the lignitic coals, should probably be called bituminous rather than lignite, as it is usually called in the region. It is of about the same composition as the Franklin, Black Diamond, and Renton (Washington) coal.[b] It will probably not make good coke, but should serve well under stationary boilers and possibly as a locomotive fuel and for other local uses. It should be especially well adapted to the generation of power by the use of producer gas in a gas engine.

### COKING QUALITIES.

A rough test of the coking qualities of the coal from tunnel No. 2 on Chickaloon Creek (see p. 93) was made during the summer of 1905, by coking a large pile of coal under a covering of stones and dirt. The resulting coke was hard and firm and had a good ring and a good texture. The test showed conclusively that a satisfactory grade of coke can be produced.

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[a] As the name is generally used in the trade, but not according to Frazer's definition.
[b] Markets for Alaska coal, p. 28 of this bulletin.

*Analyses and tests of Matanuska coals.*

| No. of sample. | Locality. | Thickness of coal seam in feet. | Moisture in air-dried sample.[a] | Total moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Calories[b] per pound of coal. | Recalculated. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Fuel elements. | | Fuel ratio. |
| | | | | | | | | | | Volatile matter. | Fixed carbon. | |
| 1 | Between Boulder and Hicks creeks (anthracite) | 38.0 | (c) | 2.55 | 7.08 | 84.32 | 6.05 | 0.57 | 7,613 | 7.75 | 92.25 | 11.90 |
| 2 | Chickaloon Creek, tunnel No. 2 | 12.3 | 0.98 | 2.58 | 19.14 | 67.46 | 10.82 | .57 | | 22.10 | 77.90 | 3.52 |
| 3 | Chickaloon Creek, tunnel No. 2 (selected) | 5.2 | (c) | .90 | 19.60 | 74.60 | 4.90 | .60 | 8,260 | 20.81 | 79.19 | 3.81 |
| 4 | do | | (c) | 1.06 | 12.76 | 78.96 | 6.28 | .90 | | 13.91 | 86.09 | 6.15 |
| 5 | Chickaloon Creek, tunnel No. 3 | 7.0 | 1.46 | 2.46 | 17.01 | 53.23 | 27.30 | .84 | | 24.22 | 75.78 | 3.13 |
| 6 | Chickaloon Creek, tunnel No. 5 | 7.9 | 1.00 | 2.90 | 17.47 | 56.15 | 23.48 | .46 | | 23.73 | 76.27 | 3.21 |
| | Average of analyses 2-6 | | | 1.98 | 17.20 | 66.08 | 14.56 | .67 | | 20.95 | 79.05 | 3.77 |
| 7 | Matanuska River, south side, 3 miles above Chickaloon Creek | 7.0 | 2.76 | 4.36 | 18.92 | 61.19 | 15.53 | .37 | | 23.62 | 76.38 | 3.23 |
| 8 | do | 7.0 | (c) | 4.15 | 20.63 | 59.62 | 15.60 | .34 | | 25.71 | 74.29 | 2.89 |
| 9 | Coal Creek, three-fourths mile above mouth | 5.0 | 1.44 | 2.24 | 23.08 | 70.21 | 4.47 | .50 | | 24.74 | 75.26 | 3.04 |
| 10 | do | 5.0 | (c) | 1.88 | 22.51 | 71.65 | 3.96 | .44 | | 23.91 | 76.09 | 3.18 |
| 11 | Coal Creek, three-fifths mile above mouth | 8.6 | 2.64 | 6.74 | 14.96 | 65.83 | 12.47 | .44 | 6,649 | 18.52 | 81.48 | 4.40 |
| 12 | do | 8.6 | (c) | 5.83 | 18.24 | 63.03 | 12.90 | .47 | | 22.44 | 77.56 | 3.46 |
| | Average of analyses 7-12 | | | 4.20 | 19.72 | 65.26 | 10.82 | .42 | | 23.14 | 76.86 | 3.32 |
| 13 | Kings Creek, west bank, upper bridge | 9.9 | 1.13 | 2.93 | 21.85 | 63.09 | 12.13 | .59 | 7,419 | 25.72 | 74.28 | 2.89 |
| 14 | do | 9.9 | (c) | 1.22 | 24.15 | 62.65 | 11.98 | .52 | | 27.82 | 72.18 | 2.59 |
| 15 | Kings Creek | | (c) | 1.15 | 23.09 | 69.34 | 6.42 | .89 | | 24.98 | 75.02 | 3.00 |
| 16 | do | | (c) | .50 | 22.00 | 70.50 | 7.00 | | | 23.78 | 76.22 | 3.20 |
| | Average of analyses 13-16 | | | 1.45 | 22.77 | 66.40 | 9.38 | .67 | | 25.57 | 74.43 | 2.91 |
| 17 | Young Creek, 3 miles above trail | 1.0 | (c) | 2.50 | 28.32 | 58.82 | 10.36 | .58 | | 32.50 | 67.50 | 2.08 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average of analyses 2-16 (bituminous coals) | ....... | ....... | 2.71 | 20.23 | 65.39 | 11.60 | .57 | ....... | 23.65 | 76.35 | 3.23 |
| 18 | Eska Creek, 3 miles above trail | 2.6 | (c) | 5.56 | 36.52 | 51.32 | 6.60 | .42 | ....... | 41.58 | 58.42 | 1.41 |
| 19 | ....do | 3.3 | (c) | 6.60 | 34.30 | 48.23 | 10.87 | .41 | 6,299 | 41.56 | 58.44 | 1.41 |
| | Average of analyses 18-19 | ....... | ....... | 6.08 | 35.41 | 49.78 | 8.23 | .42 | ....... | 41.57 | 58.43 | 1.41 |
| 20 | Tsadaka Creek, 4 miles above trail | 6.0 | (c) | 4.03 | 34.84 | 49.31 | 11.82 | .38 | ....... | 41.40 | 58.60 | 1.42 |
| 21 | Tsadaka Creek, 4½ miles above trail | 11.7 | 5.45 | 10.05 | 36.05 | 48.90 | 5.00 | .25 | ....... | 42.44 | 57.56 | 1.36 |
| | Average of analyses 20-21 | ....... | ....... | 7.04 | 35.45 | 49.10 | 8.41 | .32 | ....... | 41.92 | 58.08 | 1.39 |
| | Average of analyses 18-21 (low-grade bituminous coals) | ....... | ....... | 6.56 | 35.43 | 49.44 | 8.32 | .37 | ....... | 41.74 | 58.26 | 1.40 |

[a] Determined by drying in the open air until weight becomes constant.

[b] A calorie is the amount of heat necessary to raise the temperature of 1 pound of water 1° C. It is equal to 1.8 British thermal units.

[c] Not determined.

1-3, 5-7, 9, 11, 13, 17-21. Sampled by G. C. Martin. Analyses by F. M. Stanton, U. S. Geol. Survey coal-testing plant, St. Louis, Mo.
8, 10, 12, 14. Sampled by Wm. Griffith and G. C. Martin. Analyses by A. S. McCreath, Harrisburg, Pa.
15. Sampled by George Jamme. Analysis by C. C. Bogardus, Seattle, Wash. Published in Bull. U. S. Geol. Survey No. 259, 1905, p. 170.
16. Sampled by Frank Watson. Analysis by Wm. H. Stowell & Co., Seattle, Wash.

## MINING CONDITIONS.

There are no serious difficulties affecting the possibilities of mining these coals. The dips are so steep (10° to 60° on the anthracite, 18° to 85° in the east end of the bituminous area, and 20° to 44° in the west end of the bituminous area) that some method of stoping will have to be used. Miners who are accustomed to the steep dips in some of the coal mines of Washington and British Columbia will have no difficulty in this field. Drifts can be run from the level of the main streams and enough coal found above drainage to supply the mines for some time. It will ultimately be necessary to resort to slope or shaft mining. These methods (or tunnels across the measures from the upper floor of the Matanuska Valley) will probably have to be used in the anthracite area very soon. There is an abundant local supply of wood for building and mining timber.

It will be necessary to wash the coal from some of the seams. In this way the percentage of ash can be reduced from 10, 12, 15, 23, and 27 per cent to less than half and probably in some cases to a quarter of these figures. The tests at the coal-testing plant of the United States Geological Survey showed instances [a] where the percentage of ash was reduced as follows:

*Effect of washing coal.*

| Percentage of ash in— | |
|---|---|
| Raw coal. | Washed coal. |
| 22.44 | 9.42 |
| 13.40 | 7.16 |
| 28.39 | 7.59 |
| 13.81 | 6.22 |
| 10.59 | 5.86 |
| 9.99 | 6.33 |
| 9.75 | 7.49 |
| 25.05 | 8.14 |
| 16.00 | 10.25 |
| 15.22 | 10.28 |

It is probable that with a plant adapted especially to some particular coal and with employees experienced in handling that coal, even better results could be obtained.

## TRANSPORTATION AND MARKETS.

None of this coal can be used until a railroad is built to tide water. The Alaska Central Railway, now building from Seward to the interior, is expected to tap this coal field. The coal may then find a market for use as motive power on the railroad; for fuel in the towns and mines which may grow up along the line of the railroad and at its termini; for coke at the possible Alaska smelters; for bunker coal on the ocean and river steamers touching at the termini of the railroad, and for export. The question of markets and of competition with other fuels is discussed in detail in another paper.[b]

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[a] Preliminary report on the operations of the coal-testing plant of the U. S. Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Bull. U. S. Geol. Survey No. 261, 1905, pp. 60-73.

[b] Martin, G. C., Markets for Alaska Coal, pp. 18-29 of this bulletin.

# THE HERENDEEN BAY COAL FIELD.

By Sidney Paige.

## INTRODUCTION.

The presence of coal in the Herendeen Bay region has been known for a number of years, but though several attempts have been made toward its exploitation, little has yet been mined. During the last season the writer was able to spend four days in an examination of this area incidentally to his other field work. In this time observations were of necessity hasty and only a small area (2 square miles in addition to the route of travel) could be examined.

Herendeen Bay is an arm of Port Moller, with which it forms the only deep embayment in the Bering Sea side of the Alaska Peninsula. (See map, Pl. II.) The bay lies between latitudes 55° 40′ and 55° 55′ north and longitudes 160° 37′ and 160° 56′ west. The coal field visited occupies an area of about 1 square mile, 5 miles from the head of the bay and 1½ miles from the east side. (See sketch map, fig. 6.) The peninsula is here nearly severed by deep indentations of the coast line, Port Moller and Herendeen Bay on the Bering Sea side approaching within 8 miles of Portage and Stepovak bays on the Pacific side.

Portage Bay is narrow and V-shaped, mountains rising steeply 1,800 feet or more from the water's edge. Near its seaward end a small arm indents its eastern shore. Stepovak Bay, on the other hand, is a wide, rough, semicircular embayment whose northernmost shore approaches within about 8 miles of Port Moller.

Herendeen Bay and Port Moller, which together make a broad reentrant in the otherwise regular coast line, are separated by a tongue of land narrowing from a width of about 14 miles near their heads to a sharp point at their common entrance. The mouth of Herendeen Bay is narrowed by the presence of Deer Island, but there is a good channel between it and the mainland.

The water varies in depth, being 25 to 40 fathoms near the head of the bay and 10 to 14 fathoms as the entrance is approached. These depths are confined to a narrow channel, especially in the outer parts. Port Moller, except for a small channel midway between its shores, has widely developed tidal flats.

The chain of mountains which forms the backbone of the Alaska Peninsula is the dominating topographic feature of the region. The highest peaks, from 2,500 to 3,000 feet in elevation in the vicinity of Herendeen Bay, are sharp and rugged, cirques and other evidences of glacial erosion being common on the upper slopes. The range is broken by a low divide 500 feet in elevation, 3 miles from the Pacific side, from which streams flow northward and southward, emptying into Herendeen and Portage bays, respectively. An excellent trail crosses at this point. The northward-flowing stream descends gradually to the bay, its valley flattening and broadening as the sea is approached. One mile from its mouth a tributary enters from the west, the two forming a broad valley of very low grade. The southward-flowing stream is more precipitous in its fall and holds its grade until within one-half mile of Portage Bay, when it crosses a narrow strip of lowland.

The slopes on either side of the trail rise to the general level of the mountain range. Two large streams besides that already described enter the head of Herendeen Bay on its eastern side. They occupy broad, flat valleys, rising with easy grades to the mountains farther east. One of these, Lawrence Creek, enters 2 miles south of the coal field and flows slightly south of west. Near its head a fork enters from the southeast. The second stream, Grass River, flows northwestward and enters Herendeen Bay 1 mile south of Lawrence Creek and 1½ miles from the head of the bay. The two streams are separated by a steep ridge.

Coal Creek is a short stream entering from the east, 5 miles from the head of the bay. In its upper course it falls rapidly, but near its mouth a well-defined alluvial plain is formed.

The seaward extension of parallel ridges and the shallow depths found in the bays indicate a period of subsidence, when partial drowning of the drainage occurred, followed by a silting up of the valleys and in part of the bays.

A small bay at the mouth of Coal Creek affords an excellent harbor, with good anchorage, entirely protected from storms, within a mile and a half from the outcrop of coal visited.

Vegetation on this portion of the peninsula is confined to the valleys and the lower slopes of the hills. Willow and alder, with plants of a herbaceous nature, are found. Timber of sufficient size for even local use is entirely lacking.

Though it is said that at times during the winter months ice completely covers the bay, it is very improbable that its thickness would interfere materially with the navigation of an ocean-going ship or that pack ice would be encountered in the Bering Sea so far south.[a]

The first exploitation of the field (so far as the writer is aware) was undertaken in 1889 by a corporation under the name of the Alaska Mining and Development Company. Two drifts were run, one about 200 feet, the other about 300 feet in length, on a coal seam of 4 feet average thickness. The coal was brought to the water front by a steam motor on a small tramway, and several hundred tons were taken out in 1890, of which the U. S. S. *Albatross* used between 200 and 300 tons. The results of this test[b] will be mentioned later.

After driving the drifts the above distances the seam was lost, presumably by a fault, and as all attempts to recover it proved unavailing the work was abandoned. Subsequently the ground was staked by Mr. C. A. Johnson, who drove a tunnel 50 feet. Since then prospecting has been carried on by the Alaska Transportation and Coal Company.

Acknowledgments are due Mr. Geo. Jamme for assistance rendered the writer before his visit to the field.

## GEOLOGY.

Four distinct sedimentary horizons have been recognized in the area examined, viz, Oligocene, Upper Cretaceous, Lower Cretaceous, and upper Jurassic. Igneous rocks were observed on the eastern side of the peninsula overlying sediments, but their structural relations are not known.

The stratigraphic column of sediments, so far as determined, is as follows:

*Sedimentary rocks of Herendeen Bay coal field.*

| Age. | Lithology. |
|---|---|
| Kenai (not observed by writer) | Shales (plant remains), possibly coal-bearing. |
| Relations unknown. | |
| Upper Cretaceous | Conglomerates, sandstones and shales (plant and invertebrate remains), coal-bearing. |
| Unconformity (indicated by faulting. | |
| Lower Cretaceous | Sandstones (invertebrate remains). |
| Probably conformity. | |
| Upper Jurassic | Sandstones (invertebrate remains). |

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[a] The general southern limit of the ice is from Bristol Bay to the vicinity of St. George Island and thence about west-northwest to the Siberian coast. See Jarvis, Capt. D. H., U. S. Revenue-Cutter Service, Bull. U. S. Coast and Geodetic Survey No. 40.

[b] Dall, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 805.

### KENAI.

The Kenai horizon is represented by a fine argillaceous shale, yellow in color and carrying fossil plants.

In 1890 Charles H. Townsend, then naturalist of the U. S. Fish Commission steamer *Albatross*, collected fossil plant remains which, on examination by F. H. Knowlton, proved to be of Kenai (Oligocene) age.[a]

That the Oligocene sediments were not observed by the writer may be due, first, to the hasty nature of the visit, and, second, to the fact that the matrix in which the fossils occurred was a soft argillaceous shale in a new-cut bank, which since the time of the collection has become a mass of mud.

### UPPER CRETACEOUS.

The coal-bearing rocks are a series of conglomerates, sandstones, and shales whose lithology throughout does not show much variation. The conglomerate is of rather uniform texture, dark brown to gray in color, and composed of pebbles from 1 inch to 2 inches in diameter within a sandstone matrix. Quartz, chert, sandstone, and greenstone make up the greater part of the pebbles. The material for the most part is well rounded.

The sandstones are of medium grain, distinctly bedded, and in color range through dark browns to yellows and light grays.

Plant fossils were abundant, and marine shells were found at one locality. The former were submitted to F. H. Knowlton for determination, the latter to T. W. Stanton.

An extract from the report of Doctor Knowlton follows:

> Coal Creek (see map, fig. 6), right branch below first side stream:
>     Anomozamites cf. A. Schmidtii Heer.
>     Cone, probably of Sequoia.
>     Fragments of dicotyledons.
> Right bank of Coal Creek, first tunnel:
>     Sequoia sp.?
>     Pterophyllum cf. P. concinnum Heer?
>
> The age of these beds, as indicated by the meager plant remains, is Cretaceous, and probably similar to the beds on Chignik Bay from which Doctor Stanton obtained a Cretaceous flora.
>
> One-half mile above left branch of Coal Creek, 200 feet above fork right branch Coal Creek, big exposure left fork Coal Creek, the plant remains, aside from a fragment of a dicotyledon, consist entirely of delicate coniferous branchlets. This species was at first supposed to be *Taxodium distichum miocenum*, but more careful study appears to indicate that it is an undescribed species of *Sequoia*. The age of these beds is uncertain, but is probably similar to that of the other lots. None of the present lots contain any of the species found in the material collected at Herendeen Bay by Townsend.

The following is an extract from the report of Doctor Stanton:

> The lots that are the most interesting, because they are entirely new to the region, are those from the Upper Cretaceous. These are from the following localities: (1) Big exposure on left fork of Coal Creek, just above coal; (2) 200 yards above left fork of Coal Creek; (3) just above Johnson tunnel.
>
> The last-mentioned lot contains only fragments of *Inoceramus* and the age is somewhat questionable, but the other two lots contain abundant and well-preserved examples of *Inoceramus digitatus* Sowerby, which is a peculiar type known only from the Upper Cretaceous. The same species has been found associated with coal at Chignik, and it also occurs in the coal-bearing Cretaceous rocks of Vancouver Island.

### LOWER CRETACEOUS.

The sandstone of this age, where observed in the neighborhood of the coal, was of medium grain and of greenish tinge. Marine invertebrate fossils were found in abundance at two localities. Doctor Stanton says:

> The two lots from "divide above Johnson tunnel stream" and from the "beach one-fourth mile west of the mouth of Coal Creek" contain abundant specimens of an Aucella of the type of *Aucella crassicolis* Keyserling, which indicates that the rocks are probably of Lower Cretaceous age. This very convex form of Aucella is not known to occur as low as the Jurassic, and the genus is confined to the upper Jurassic and Lower Cretaceous rocks.

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[a] Proc. U. S. National Museum, vol. 17, No. 998, 1894, pp. 207-240.

### UPPER JURASSIC.

The upper Jurassic sediments, best developed on the shores of Herendeen Bay south of Coal Creek, outcrop in massive bluffs, where weathering has caused the formation of large spherical masses weighing, in some instances, several tons. Long cylindrical shapes are common, and conchoidal fracture characterizes the formation.

Doctor Stanton says of the fossils collected in these rocks:

> Three small lots from the "bluff south of Moss Valley" contain *Aucella* of another type, resembling *Aucella pallasi* Keyserling, which is a Jurassic form. With this species are also specimens of *Pleuromya* and *Belemnites*. These lots are believed to be from the Jurassic.
>
> The single specimen from "bluff south of Lawrence Creek" shows only the imprint of a fragment of an ammonite too imperfect for even generic determination.

It will be seen from the above that in the immediate vicinity of the coal there are found three distinct horizons—viz, Oligocene, Upper Cretaceous, and Lower Cretaceous—and that in the neighborhood of Herendeen Bay there are in all four horizons, as the upper Jurassic was found on the shore of the bay in a "bluff south of Moss Valley."

The coal-bearing beds of Upper Cretaceous age may be correlated with the Upper Cretaceous beds of Chignik Bay and the Upper Cretaceous coal-bearing strata of Vancouver Island. The coal beds near Nulato, on Yukon River, are also of Upper Cretaceous age.

Nearly due east from the Herendeen Bay field, in an air line approximately 14 miles distant, W. H. Dall collected on the shores of Port Moller fossils of Mesozoic age (Lower Cretaceous)—*Belemnites*, *Cyprina*, and *Aucella*—determined by C. A. White in 1884.[a]

Nearly south of this locality, on the southern side of the peninsula, at Stepovak Bay, Charles Palache collected invertebrate fossils of Eocene age,[b] determined and described by W. H. Dall,[c] while on the north end of Unga Island, of the Shumagin group, both Kenai and Miocene beds are exposed.[d] Therefore in an area approximately 40 miles square are found strata ranging from upper Jurassic to Miocene.

### IGNEOUS ROCKS.

Though in the neighborhood of the coal no rocks of an igneous character were observed, an area of considerable extent to the south, on the trail between Herendeen and Portage bays, is characterized by volcanic rocks. The high ridge forming the north side of the valley of Portage Creek, approximately 1½ miles from Herendeen Bay, is composed of a dark basic crystalline rock found to be a quartz-diabase. This rock and a second type, provisionally called a monzonitic porphyry, were found at several isolated points along the trail. The exact relation they bear to each other or to the underlying sandstone series is not known.

Rocks of intrusive origin, resembling more or less the above types, were noted by Charles Palache[e] at Chichagof Cove, Stepovak Bay.

### STRUCTURE.

Only the main structural features were determined, special attention being given to the position, condition, and possible continuance of the coal seams.

The coal-bearing strata of Upper Cretaceous age, including both sandstones and conglomerates, strike in a direction slightly north of east and dip rather steeply (30°–55°) to the north. Local variations are not uncommon, strikes varying from N. 65° E. to N. 80° E. (See fig. 6.)

The rocks of Lower Cretaceous age (not coal bearing), forming the left side of the valley of Coal Creek, strike in a southeast-northwest direction and dip to the northeast at angles of

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[a] Bull. U. S. Geol. Survey No. 4, 1884, pp. 10–15.

[b] Harriman Alaska Expedition, vol. 4, New York, 1904, pp. 69–88.

[c] Idem, pp. 99–124.

[d] Correlation papers—Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 240–242. See also Dall, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 807–811.

[e] Geology about Chichagof Cove, Stepovak Bay: Harriman Alaska Expedition, vol. 4, New York, 1904, pp. 69–88.

14° to 22°. (See fig. 6.) On the ridge at the head of the creek a strike of S. 34° E. is observed. It will be noticed that these strikes are about at a right angle to those of the coal-bearing series to the north, and that the dips are lower.

It was in these sandstones (at the head of Coal Creek) that marine fossils of Lower Cretaceous age were found, while topographically lower, in the creek, fossils of undoubted Upper Cretaceous age were collected. A glance at the sketch map (fig. 6) will make clear the difference in strike between the beds north and south, respectively, of the course of Coal Creek and an imaginary line followed in the direction of that course (see dotted line on map), representing the approximate northward boundary of the Lower Cretaceous in this vicinity.

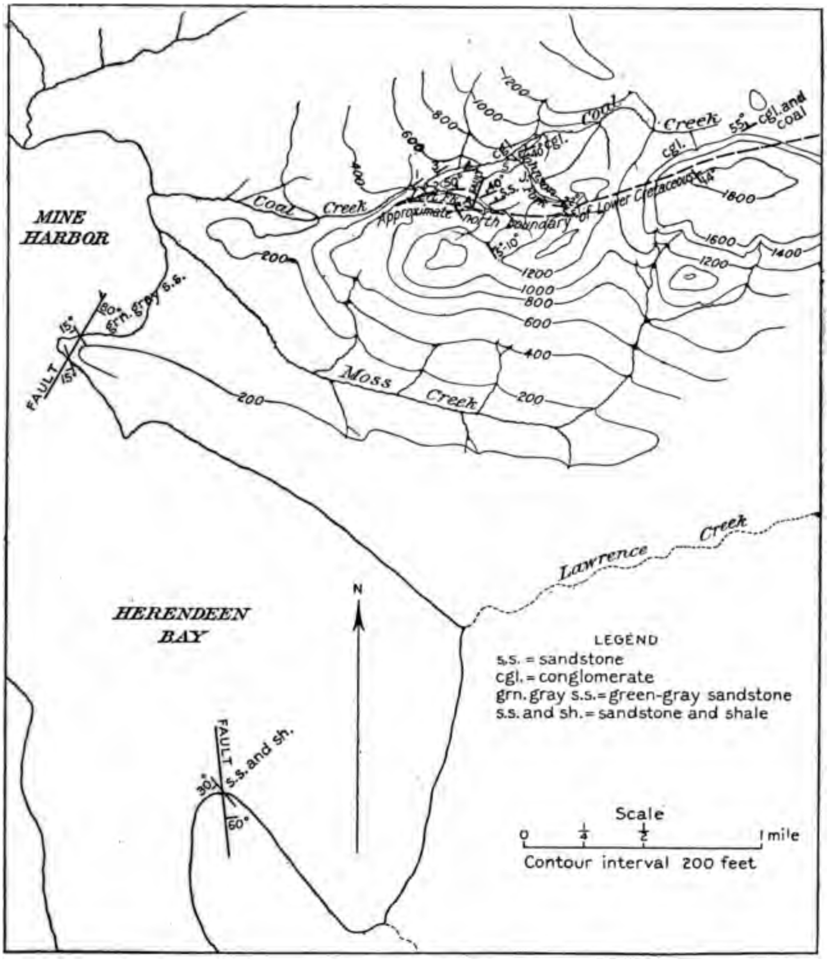

FIG. 6.—Sketch map of Herendeen Bay region.

Evidence points to the conclusion that the coal-bearing rocks are not continuous in an undisturbed condition south of a fault of considerable magnitude which strikes in a general east-west direction. There is a possibility that the uplifted block (to speak relatively) may be of no great width, but data concerning this point are not at hand.

The loss of the coal in the Johnson tunnel (to be mentioned later) is significant in connection with the above facts.

At a point marked A on the map (fig. 6, p. 105) a normal fault was observed in the coal-bearing sandstones, its direction being slightly east of north and its dip 20° E. The downthrow, roughly estimated at 30 feet, was to the east, and the disturbed beds could be plainly traced on either side. It is noteworthy that this fault occurs in a bluff containing seams of coal of considerable thickness.

On the shores of Herendeen Bay two faults were seen—one on the point south of Moss Creek Valley, the other on a point south of Lawrence Creek Valley. While both dip to the east at steep angles (80° and 60°, respectively), their line of strike is not in exact accord, the former striking in a northeast direction and the latter striking slightly west of north.

It may be noticed by a glance at the map that the strike of the beds on which these faults occur agrees very nearly with that of the beds just south of the coal, though the dips are in opposite directions. It seems probable, therefore, that the latter beds occupy the northern limb of an anticline, though near the crest, as evidenced by the low dip. In tracing the beds southward along the shores of Herendeen Bay a change of dip was observed, first flattening and then gradually steepening as the faulted beds were approached.

Close folding was not noticed in any portion of the field and only by observation over an extended area, as shown above, could evidence of any folding whatever be detected.

## DESCRIPTION OF THE COAL.

Owing both to the early date at which the coal field was visited and to the neglected state of the workings only a few observations could be made on individual coal seams. What is said to be the largest and most promising series of beds—those at the Johnson tunnel—were entirely covered with snow, and all information concerning them was received from those who in times past had worked on the property. Measurements of coal beds made by the writer were confined to two localities—in the big exposure on the left fork and in the conglomerate at the head of the creek.

Just below the left fork (see fig. 6, p. 105), at locality No. 1, a drift was run 150 feet along the strike (N. 40° E.) on a seam 3½ feet thick. The seam was lost and the entrance is now caved in. At locality No. 2, at the mouth of the left fork, a drift was driven on a seam striking N. 85° E., for 200 feet, when again the coal was lost. As in the first instance the entrance had caved. This seam is that from which the Alaska Development Company mined approximately 500 tons in 1889 and from the coal of which the analysis given later (p. 108) was obtained. At locality No. 3 a drift now caved was run on a seam. No details could be obtained. In sandstone, much jointed and crushed, at locality No. 4, a tunnel was driven N. 85° E. Caving has entirely destroyed the entrance. At locality No. 5 the same condition exists.

By far the most work has been done at the Johnson tunnel, marked J in fig. 6. The following notes were obtained from a miner:

A drift was driven approximately N. 50° E. for a distance of 110 feet on a coal seam of 4 feet 6 inches average thickness. Much crushing was in evidence at this point, and the coal was lost.

Though the tunnel was continued to a total distance of 205 feet from the entrance, no sign of the lost seam was found. Moreover, 20 feet from the face a drift for 29 feet to the left, on the level, at an angle of 45°, also failed to catch the coal.

Ninety feet from the entrance an upraise was driven to the right on a slope of 45° up the bed. It continued at this angle for 90 feet, when a turn was made and the remainder driven vertically to the surface. Forty feet up the raise a drift along the coal in the direction of the main drift was driven for 32 feet, when the coal pinched out.

A horizontal crosscut to the right, 93 feet long, from the foot of the upraise passed only two seams each 18 inches thick and a few small stringers.

At the mouth of the main drift a crosscut tunnel was driven in the hillside opposite in a westerly direction for 100 feet without encountering seams of importance.

There seems to be no reasonable doubt that faulting has disturbed these beds, and the evidence obtained from the fossils indicates that the movements have been of sufficient magnitude to entirely cut off the coal in a southerly direction.

The coal from the Johnson drift is solid, blocky, and clean, with an irregular fracture. Particles of amber are present. A specimen taken from a sack which had lain exposed for two years to the sun and rain was still in excellent condition. This fact is not in accord with the statement given later in the report of the engineer of the U. S. S. *Albatross*.

On the right bank of Left Fork, between an eighth and a quarter of a mile from the main creek, a steep cut is made by the creek through the coal-bearing sandstones exposing a number of seams. Measurements taken down the face gave the following section:

*Section of coal beds on Left Fork of Coal Creek.*

| | Ft. | in. |
|---|---|---|
| Crushed coal | 7 | |
| Shale | 9 | |
| Bony coal | 1 | |
| Shale and sandstone | 6 | 6 |
| Coal, crushed | | 8 |
| Coal, fairly solid (obscured partially by slide) | 10 | |
| Shale, carbonaceous | 3-4 | |
| Covered by slide | 20 | |
| Coal with bone (details not observed) | 12 | |
| Shale and coal | 4 | |
| Coal | 2 | 8 |
| Shale | 6 | |
| Coal | 3 | |
| Remainder hidden by slide. | | |

The above section was measured entirely on the surface, time not permitting sufficient excavation to reach clean material where more accurate details would have been available. It is probable that in a clean section the coal would measure less.

It was through this bluff that the 30-foot fault was observed. The old A. C. Co. tunnel (No. 2 on the map, fig. 6, p. 105) was apparently run on one of this series of seams (probably lower than the section given), and as it pinched out between 200 and 300 feet from the entrance the presence of a second fault near the mouth of Left Fork might be inferred.

On the divide between the east and west drainage at the head of the main fork of Coal Creek coal croppings were observed at an elevation of 1,850 feet. The strike of the rocks at this point was N. 40° E. and the dip 55° N. One seam of 5-foot average thickness was observed, and across a surface of approximately 100 feet numerous croppings of weathered coal were exposed.

In 1890 the United States Fish Commission steamer *Albatross* tested 80 tons of coal from the A. C. Co. tunnel which, with due consideration for the fact that the coal may have contained extra dirt from careless mining, was probably fairly representative of the field.

The following extracts are from the report of the engineer of the *Albatross:*[a]

> The average consumption of the coal was at the rate of 25 pounds per square foot of grate per hour. The boilers furnished the same amount of steam as when we have been using a fair quality of Wellington coal, but to obtain this result we had to burn from 20 to 25 per cent more of the Herendeen Bay coal.
>
> The coal ignites readily and burns with a considerable flame, forming a loosely cohering coke which breaks up into small pieces, thus a considerable amount of small particles of coal is lost through the grates. There was a large proportion of fine stuff in the coal which burned well, but contained an excessive amount of refuse matter.
>
> The refuse amounted to 26 per cent of the total weight of coal consumed. It consists of ash and cinders, no glassy clinker being found. The smoke produced is lighter in color than that of Wellington coal and less soot is formed.
>
> * * * It will be, however, absolutely necessary to store this coal under shelter, as it appears to absorb moisture readily and the constant rains that have prevailed in this region during the present season would soon saturate it to such an extent as to greatly diminish its value as a fuel.

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[a] Bull. U. S. Fish Commission, vol. 9, for 1889, Washington, 1891, pp. 282-283.

An analysis of the coal was as follows:[a]

*Analysis of coal from A. C. Co. tunnel, Herendeen Bay.*

| | |
|---|---|
| Moisture | 3.43 |
| Volatile matter | 39.00 |
| Coke | 47.40 |
| Ash | 10.17 |

The ash was of a pinkish color and free from clinker, the coke dull and slightly coherent. Percentage of sulphur was 0.44.

It is said that sufficient gas was encountered in the workings to require the use of the safety lamps.

## SUMMARY.

The coal of Herendeen Bay may be classed as bituminous and is of a very fair quality. It is clean, blocky, and solid, with an irregular fracture. Though rather high in ash (10.17 per cent), this feature does not materially affect its commercial value, as much coal is sold with quite as high a percentage.

The quantity that may be depended on is uncertain. A more extensive area to the north and west may be underlain by coal, and the possibility is worthy of consideration. Coal is known to exist at Coal Bluff, on the east shore of Herendeen Bay, and on good authority is reported in the territory lying to the west and north on the opposite side. Further exploration is necessary to determine the truth of these reports. There is no doubt that the field, so far as examined, is badly faulted, and that attempts to follow several seams have all proved unsuccessful.

The fact that the entire region has suffered severe faulting would generally be detrimental to the economical exploitation of any beds whatever, but it is possible that unaffected blocks may be found of sufficient size to allow successful development on a small scale. The topography of the region is such that no difficulties would be found in building tramways from the field to tide water. In no case, however, should plans for extensive investment be formed without careful study of the field.

The question of a market would be of paramount importance should exploration ever provide sufficient coal to warrant shipping. When railways tap the Matanuska and Bering River fields to the northeast, coastal towns will in all probability derive their fuel supply from these sources.

The canneries in the neighborhood of Bristol Bay require a certain quantity of coal each season, and this market would seem within the range of the Herendeen Bay field. It must be remembered, however, that the cannery ships which move the pack in the fall arrive loaded with coal at Bristol Bay points in the spring, and but for this fact would of necessity sail without full cargo. This factor would surely enter into any estimates of the cost of coal to the canneries.

At Nome during the last winter outside coal sold at $17.50 a ton. A portion of this amount ($2.50 to $5 a ton) must be charged to lighterage, which would equally affect any imported coal. Nevertheless, this would seem to be a possible market.

A factor of growing importance in estimating the cost of fuel supply at coast points is the increasing use, because of greater economy, of California crude oil.

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[a] Dall, W. H., Report on coal and lignite of Alaska. Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 807.

# YUKON PLACER FIELDS.

By L. M. Prindle.

## INTRODUCTION.

Mining in that part of the Yukon basin which lies in Alaska has, in 1905, been confined to the gold placers. In fact, the placer gold is as yet the only resource which has been developed, with the exception of a little coal sporadically mined along Yukon River. Gold-bearing lodes are reported from various districts, but nothing has been found which can be commercially developed under the present high cost of transportation. It is therefore foreign to the purpose of this paper to discuss the probabilities of the future growth of a quartz-mining industry in this field. It should be said also that as yet there is little detailed information on which to base such a discussion. Certain it is that only in small areas does the alluvial gold occur in sufficient quantity to permit profitable exploitation. Present developments indicate that conditions for the occurrence of workable placers exist in the Fortymile, Birch Creek, Fairbanks, and Rampart regions. Gold has, however, been found at localities outside of these districts; for instance, in the Salcha basin and in the Bonnerfield and Kantishna districts. Placer gold is also reported to occur in the gravels of Innoko River, an easterly tributary of the lower Yukon.

The Koyukuk district, in the extreme northern part of the Yukon basin, has been a gold producer for many years. It appears to lie outside of the zone which includes the more southerly camps. In mode of occurrence, bed rock, etc., the placers of the Koyukuk [a] closely resemble those of the Yukon-Tanana region.

In general terms, the belt of metamorphic rocks which enters Alaska at the international boundary, between the Yukon and the Tanana region, may be said to be auriferous. This belt stretches westward, or slightly north of west, between the rivers, and touches the Yukon in the Ramparts. What is probably a southwesterly extension of the same belt is found in the placer-gold districts lying south of the Tanana, but the details of correlation must await further study.

The outlines presented above define the metamorphic rocks in which the placer gold finds its source, but the distribution of the placers is determined by laws only imperfectly understood.

Placer mining in the interior of Alaska during 1905 has been unusually successful. A factor which contributed largely to this result was the abundant summer rainfall, which increased in quantity from the boundary westward, leaving only the Fortymile region to suffer from lack of water. The producing streams are, for the most part, small, the snowfall is generally light, and the streams depend in great measure for their supply of water on the rainfall. Since up to the present time no extensive ditches have been constructed, there is in every region a dependence on the supply from streams in the immediate vicinity; and if this fails, the work for the summer is largely at a standstill. The rainfall during the working season, therefore, exerts a controlling influence on the prosperity of a region where conditions are otherwise most favorable for success.

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[a] Schrader, F. C., Preliminary report on a reconnaissance along the Chandlar and Koyukuk rivers in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 482-485.

The transportation facilities also are of great importance in the development of a region. During the season of 1905 they were good on Yukon River and on the Tanana as far as Fairbanks. The transportation of supplies by steamer from Fairbanks up the Tanana, however, is a more difficult problem, and, although preparations were made especially for this work, there was inability in many cases to deliver supplies at points for which they had been ordered. The piece of work which stands out most clearly in the direction of better transportation is that of the railroad from Fairbanks and Chena to Pedro Creek. The crying need is for a railroad which will connect these placer districts with Pacific tide water. Until this is done the Yukon region can not take its rightful position as a gold producer.

The trend of development in the older regions has been toward methods adapted for working large quantities of gravel at a lower cost. Hydraulic plants have been installed and the success attained by dredging in the Dawson country has stimulated interest in the introduction of dredges. It must be remembered, however, that either of these methods requires special conditions favorable to its use and also skillful management in order to insure success. In the Fairbanks region mining methods are directed toward greater efficiency in thawing frozen gravel. The older regions have held their own, but the center of production has shifted to the Tanana Valley.

The following statement of conditions is based in part on information gathered by the writer and his assistant, Adolph Knopf, in the course of a geologic reconnaissance from the international boundary to Fairbanks, and in part on information gathered from various other sources. By means of the cordial cooperation of a number of men resident in the different districts, information has been gathered by Mr. Brooks, through correspondence, regarding the developments in fields not examined by the Survey in 1905. As the Fairbanks region was personally examined by the writer, and as this is the largest producer, it will be treated in greater detail than the other camps.

## FAIRBANKS REGION.

### INTRODUCTION.

The Fairbanks region includes those gold-producing areas of the Tanana Valley which are about 260 miles above the point where the Tanana joins the Yukon. These are all north of the river and within 25 miles of its navigable waters. They comprise parts of the valleys of a few small neighboring streams, most of which belong to the drainage areas of southwestward-flowing tributaries of Tanana River. (See map, fig. 7.)

The most important part of the Fairbanks region may be roughly considered as embracing the country demarcated on the northwest and southeast by two of the larger southwestward-flowing tributaries of the Tanana—Chatanika[a] and Chena rivers, which are about 25 miles apart—and including areas extending to a distance of about 25 miles northeast from the Tanana. The productive areas have, however, thus far been confined to the valleys of a few small streams.

The general configuration of the country, the details of topography, the water and timber resources, the bed rock, the deposits thereon and their mutual relations, and all the varied elements which make up the ground plan, as it were, of every mining problem must be thoroughly considered in order that there may be attained that perfect adjustment of equipment to conditions which finds expression in the maximum of economy and efficiency.

In the Tanana region there is a constant repetition of similar ridges, approximately conformable in height, separated by similar valleys, equally conformable in depth. A few short ridges and groups of hills stand out more prominently and attain altitudes of 5,000 to 6,000 or more feet, but the general level is about 3,000 feet. The bottoms of the valleys are at a level of a quarter of a mile or more below that of the inclosing ridges and have, in general, like the ridges, a uniformity of height above sea level.

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[a] Chatanika is the local name for the upper part of Tolovana River.

The presence in California of commanding mountains with large supplies of water at much higher levels than the placers rendered possible a great development of the hydraulic method. The absence of such differences in altitudes in this field has made it difficult to carry water from one valley to another by means of ditches. These must necessarily be of great length in order to reach a point of intake at a level sufficiently high to give a head for sluicing, and such a point is generally so near the source that the supply of water may be too low to give results equal to the expense involved. The hydraulic method has been, therefore, of limited application in this field.

The location of a trading post in this part of the Tanana Valley in 1901 was followed in 1902 by the discovery of gold. The region began to attract attention, and by the end of 1903, with a production of at least $40,000, had become of prospective importance. The work of 1904 resulted in a production of over half a million, and the position of the region as an important gold producer was established. The last year has been one of prosperity. The introduction of large quantities of machinery for the working of the deep frozen gravel has in almost every case met with gratifying results. It is difficult to give accurate figures regarding the year's production of gold, but from the close of the open season, in October, 1904, to the middle of September, 1905, when the Survey party left the field, it is believed to have been approximately $5,500,000, and there were still about three weeks of work before the freeze-up was expected. The general opinion among the miners was that the output from the freeze-up of 1904 to that of 1905 would approximate $6,000,000.

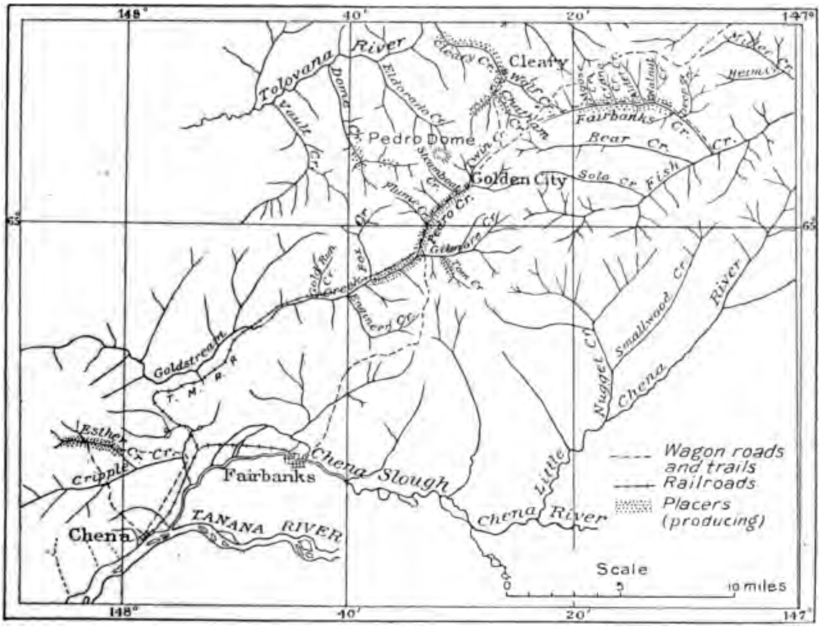

FIG. 7.—Map of Fairbanks district.

Mining has been confined mainly to Cleary, Fairbanks, and Pedro creeks and a few of their tributaries, Esther Creek, which has within the last summer been added to the list of producers, and Dome Creek, where at a few points pay has been located; but the bulk of the increase within the year has been derived from Cleary Creek.

Transportation to the Fairbanks region from outside points during the last year has been either by way of Dawson, St. Michael, or Valdez, and most of it by the first two of these routes. The Valdez route is a convenient one for many who desire to reach Fairbanks before the opening of navigation and will probably be traveled extensively during the winter season. The rates on supplies shipped from Seattle to Fairbanks vary greatly according to the freight classification under which they come. On ordinary supplies the rate has been $75 per ton. The rate on similar supplies from Seattle to Dawson has been $45 per ton, and from Dawson to Fairbanks $55 per ton. Supplies shipped in the spring from Seattle to Fairbanks by way of Dawson reach their destination earlier in the season than if shipped by way of St. Michael, as the upper Yukon is first open to navigation. First-class passenger rates from Seattle to Fairbanks by way of St. Michael have been $125; from Seattle to Dawson, $80, and from Dawson to Fairbanks, $60.

The town of Fairbanks is situated on a slough of the Tanana, near the head of what might be called easy navigation. Its population during the summer of 1905 was about 2,500. During dry seasons the quantity of water in the slough is so small that some of the steamers have difficulty in reaching the town. The larger boats that ply occasionally on the Tanana are unable to reach Fairbanks, and their supplies are left at Chena. As illustrations of the prevailing summer prices the following may be quoted: Flour, $8 to $12 per hundred pounds; beans, $12 to $15 per hundred pounds; bacon, 18 to 25 cents per pound; sugar, 12½ cents per pound; overalls, $1.25 to $1.75 per pair; picks and axes, with handles, $2.50 to $3 each; shovels, $1.75 each; manila rope, 30 cents per pound; bar iron, 15 cents per pound; steam points, $8 to $14 each; lumber, $75 to $100 per thousand feet. The town is lighted by electricity, and a large part of the business section is heated by steam from a central plant. Water is sold for domestic purposes at the rate of $3 per month. Wages for ordinary labor have been 75 cents per hour; for carpenters, $1.50 per hour; for miners, generally $5 and board, and in some cases $6 and board, per day.

Fairbanks has a daily newspaper, a school system, three banks—one of them a national bank, with currency of its own in circulation—and a court which has jurisdiction over the whole of the interior of Alaska.

The town of Chena is situated at the entrance of the slough into the main river. It is accessible for the largest boats, but has the disadvantage of being several miles farther from most of the gold-producing creeks, and thus far its development has not kept pace with that of Fairbanks. The construction of the railroad, however, will probably have a favorable effect on the growth of the town.

The transportation of supplies from the towns to the creeks, in the absence of good roads, has been a source of much trouble and expense. The railroad, however, has made conditions easier. This road connects Fairbanks and Chena and extends from an intermediate point, the junction, to the valley of Goldstream Creek, and along this valley to the junction of Gilmore and Pedro creeks, where the present terminus is located. The total length of the road is about 26½ miles. It is a narrow-gage road, and the problems of construction which the unstable, water-soaked muck presented have been well met. The difficulties of transportation from the outside to Fairbanks are well illustrated by the fact that the rails for this road were handled eleven times before reaching their destination and that six flat cars, also destined for the road, are now at the bottom of Yukon River.

Preliminary surveys have been made for wagon roads to be constructed by the Government. One is to be built from the terminus of the railroad at Pedro Creek over the divide to Cleary Creek. The summer rates during the last season from the town of Fairbanks to the most distant points of this region where mining is being done, about 25 miles, have been 12 to 15 cents per pound. The winter rate to the same points was 5 cents per pound.

The region, while dependent on the outside for the greatest part of its supplies, is in the matter of lumber and fuel mostly independent. The spruce timber along the sloughs of the Tanana and the lower parts of the valleys of its largest tributaries is of good quality and much of it exceeds 2 feet in diameter at the butt. The small spruce and birch so abundant on the hillsides furnish a supply of fuel which has not up to the present time been heavily taxed. The nearest coal is that on the Cantwell, described by Brooks as follows:[a]

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[a] *Brooks, Alfred H.*, note in The coal resources of the Yukon, Alaska, by Arthur J. Collier: Bull. *U. S. Geol. Survey No.* 218, 1903, pp. 44-46.

The coal-bearing beds outcrop for about 15 miles along the river and were traced about 4 miles to the east. The area of this coal field can be safely estimated at 60 square miles at least, and may be many times that. The beds are seldom exposed except along the river and stream valleys, for elsewhere they are usually deeply buried under Pleistocene gravels.

What promise to be workable coal beds were found at two localities during the hasty reconnaissance on which these notes are based. The most important of these are on Healy Fork, an easterly tributary of Cantwell River, which it joins from the east about 40 miles from the Tanana. The coal beds are well exposed in precipitous bluffs along the north valley wall of this stream. * * * While the beds are largely made up of sandstone, yet the layers lying immediately adjacent to the coal are most often clay and sandy shales. One bluff about 2 miles from the Cantwell was examined in some detail. In this section 200 feet of sandstone and conglomerates formed the basement member and rested unconformably on the phyllites of the metamorphic series. This bed was overlain by about 250 feet of soft sandstone, shales, and coal. In the entire section the coal aggregated about 125 feet in thickness, contained in about 15 seams. Of this 125 feet probably 60 feet were of a fairly good grade of lignite. The largest seams were 20 feet in total thickness, but included considerable bone and shale. In character the coal varied from a fibrous, impure lignite, which is entirely worthless, to lignites which may have commercial value. The lignite of better grade is of a lustrous black color, and has a conchoidal fracture. The seams were accessible only along the outcrop, where they were made up of noncoherent lignite. A sample taken almost at random from one of the larger seams was analyzed by Dr. E. T. Allen, of the United States Geological Survey, with the following result:

*Analysis of coal from Healy Fork of Cantwell River.*

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|---|---|
| Moisture | 13.02 |
| Volatile matter | 48.81 |
| Fixed carbon | 32.40 |
| Ash | 5.77 |
| | 100.00 |

This analysis shows that the coal is a fairly good lignite. In considering it, it should be borne in mind that the short time given to the study of the locality makes it quite possible that seams of better grade were overlooked.

The second locality where lignites were found is on Lignite Creek, so called, a few miles north of Healy Fork. At this place the croppings show fewer seams, and these are of less thickness. These lignites, as far as determined, were of no higher grade than those of Healy Fork. North of Lignite Creek, and apparently higher in the series, seams of fibrous, impure lignites and carbonaceous shales are not uncommonly interbedded with the sandstones. It is not likely that any of these have any prospective commercial value. In the opinion of the writer the best coals in the basin are near the base of the sandstone series.

Topographically these coal seams are exceptionally well located for mining. Though they have been known since 1898, the isolation of the locality has precluded any possibility of their development. Should a railway ever be built through Caribou Pass from Cook Inlet, as has been proposed, it is quite possible that this coal field might receive development.

## GEOLOGY.

### BED ROCK.

The country rock or bed rock throughout most of the area between Chatanika and Little Chena rivers is quartzite-schist and quartz-mica-schist, generally in thin alternating beds, in places feldspathic and very commonly containing garnets. Graphitic schists are common and there is some fairly massive crystalline limestone and some greenstone schists in places very garnetiferous. The schists have been closely folded and strike northeast and southwest. The main structural planes vary from nearly horizontal to nearly vertical. The alternating layers of the blocky quartzite-schist and the very micaceous quartz-mica-schist, which decompose readily, give rise to a bed-rock surface of varying influence on the distribution of the gold. With a blocky bed rock gold sinks along the structural planes to a distance sometimes of several feet, while the compact, clayey mass of the softer beds offers an impervious layer which gold can not penetrate.

Intrusive biotite and hornblende granites occur in parts of the area, notably in the ridge south of Gilmore Creek, on Twin Creek, a tributary of Pedro Creek, in Pedro Dome, and at the head of Chatham Creek. Some of these occurrences are porphyritic rocks with feldspar crystals an inch or more in diameter, while others are fine and even grained. All of these are comparatively fresh and have been intruded in the schists since the metamorphism of the latter. Acidic granite intrusives so common in the Fortymile region have not been observed. Recent fresh olivine-basalt, probably extrusive, is occasionally found.

Quartz veins are common in the schists, sometimes attaining a thickness of 2 or more feet, but are not so abundant that the quartz becomes a conspicuous constituent of the gravels. Stibnite has been found in places on Chatham Creek as a vein a foot or more thick in the schist, parallel, so far as could be learned, with the structure of the latter. Float of the same material at the head of Cleary and Esther creeks indicates further occurrences of this mineral. There has been much search for gold-bearing quartz in the ridge between Cleary and Pedro creeks, and a considerable area of mineralized rock to the southwest of Pedro Dome has been found that is reported to carry values.

### ALLUVIAL DEPOSITS.

The constant weathering of the rocks produces loose material of varying coarseness which covers the fresher surface beneath until removed. Outcrops of bed rock in the Fairbanks region are confined mostly to the summits of the ridges and to the steeper slopes of the valleys, while on the gentler slopes and in the bottoms of the valleys the bed-rock surface is covered with a mantle of material ranging from a few feet to over 100 feet in thickness. This mantle is composed partly of heterogeneous talus which is continually working down the sides of the valleys and partly of the material in the valley floors which has been worked over so many times by running water that it has a fairly uniform structure throughout. All of these deposits are, for the most part, frozen throughout the year.

As the streams generally flow close to one side of their valleys these deposits are mostly on one side. Their upper surface slopes gradually toward the base of the hills. The bed-rock surface, so far as known, is in general nearly flat or at least has a very gentle grade hillward from the creek. The deposits are in most cases separable into three divisions, which, from surface to bed rock, are referred to by the miners as muck, barren gravels, and pay gravel.

The muck varies in thickness from a few feet to a maximum of about 70 feet, the line of separation between it and the underlying gravels being fairly sharp. It is a black deposit containing a large amount of material derived from the decomposition of moss and other vegetation, with a considerable percentage of clay and sand, either intermingled with the organic material or as layers and thin lenses distributed irregularly through the mass. Horizontal beds of ice several feet in thickness are sometimes present.

The underlying gravels, ranging in thickness from 10 to over 60 feet, are derived from the rock occurring within the areas drained by each particular stream. As quartzite-schist is the most common bed rock and also the most resistant to the process of wear, the largest proportion of the coarse material in the gravels is composed of it. The gravels also include quartz-mica and graphitic schist, some vein quartz, and some igneous material, mostly granite. An occasional mammoth tooth and bones of other animals now extinct are also found. The coarse material, being mostly quartz-schist, occurs as more or less flattened angular pieces but slightly waterworn. Few of them exceed a foot in diameter and the proportion of bowlders is therefore small. The fine material is composed partly of smaller pieces of the more resistant rocks and partly of clay, derived from the decomposition of the micaceous and graphitic schists. There is also a small percentage of individual minerals released by the process of weathering. Though the proportion of clay in the barren gravels is small, in the pay streak it is large. All the material, both coarse and fine, is irregularly intermingled, the larger pieces being usually nearly horizontal. The deposits in general are such as would be formed by an overloaded stream.

The pay gravels resemble those above them, but contain a considerable amount of clay which adheres tightly to the gravel and to the surface of the blocky fragments of bed rock. This clay is prevailingly of a yellowish color in the more shallow diggings and of a bluish color in the deeper gravels. The proportion varies, but there is in most cases sufficient present to render the pay gravels easily distinguishable in the drifts from the barren ground above them. The thickness of the pay gravels varies from a few inches to a dozen or more feet, an average which is rather uniformly maintained over large areas. The under surface of the gravels not only rests upon the bed rock, but where the latter is blocky is found within it to a depth of from 1 to 3 feet or more. The width of the pay gravels varies in different creeks and in different parts of the same creek, but in most cases makes up only a small part of the width of the valley. Pay streaks 30 feet or less to 450 feet and, in one instance, 800 feet wide have been reported. The average width of gravels carrying values sufficient to pay for working under present conditions is probably about 150 to 200 feet and this, like the thickness, is fairly constant. The pay streaks in the valley floors often bear no uniform relation to the present stream beds.

While vertically but one pay streak has thus far been found, the great width of some of the valleys and the flatness of the underlying bed rock render possible the presence of more than one pay streak in the horizontal direction. In some places the presence of a second pay streak has been suspected and prospecting was under way last season to determine definitely whether such is the case. The gold occurs evenly distributed throughout the pay gravels, mostly near the bed rock, or occasionally chiefly within the bed rock.

The great bulk of the gold is composed of flattish pieces of various sizes up to one-fourth inch in diameter and of granular pieces, some of which are very minute. The proportion of very fine gold, however, is apparently small, and there is but little flaky gold. Nuggets form an inconsiderable part of the clean-ups; those worth a few dollars are common, however, and a few have been found of considerable value. Some of the largest were worth approximately $145, $160, $190, $233, and $529. The nuggets often contain quartz. Most of the gold found near the heads of the creeks is angular. Downstream there is in general a gradual decrease in the average size of the pieces and an increase in the amount of wear they have sustained. Nuggets, too, are less common in the lower parts of the valleys. In some cases the coarse and fine gold occur together, while in others the coarse gold is found mostly on one side of the pay streak. At occasional localities there appears to be an abrupt change from gravels carrying a large percentage of coarse gold to those immediately below on the same stream whose gold contents are chiefly fine. The values in the pay gravels which are now being exploited range from about 2 cents to 20 cents or more to the pan and there is a large part of the ground which will average about 8 cents to the pan, or about $10 to the cubic yard, or $2 to the square foot of bed rock. Some of this ground will average $3 to $3.50 to the square foot and some carries even better values. Assay values were reported ranging from $16.16 to $18.25 of gold per ounce and the gold from one locality was said to assay as high as $19.25.

The minerals most commonly associated with the gold, aside from the quartz, with which it is often intergrown, are garnet, rutile, and black sand. The proportion of the black sand is small and it is composed mostly of magnetite. Cassiterite is rather commonly found and there is some stibnite. Bismuth occurs in close association with the gold in a nugget which was found by the miners on Gilmore Creek, and was presented by them to the Survey party, and tested by Mr. Schaller in the Survey laboratory.

The frozen deposits are tough, in distinction from the muck. The gravels can not be broken with a pick and are with difficulty rent by explosives. A sudden caving in of the ground undermined in drifting is rare, the sinking usually being so gradual as to permit the removal of mining apparatus. In such cases a parting often takes place between the gravels and the overlying muck, leaving the latter as a roof. The solidly frozen gravels are practically impermeable to the surface waters and to any underground water that may be present and the underground mining operations are comparatively dry. Unfrozen areas are often encountered, and where they occur in the deeper ground the presence of "live water" adds to the expense of mining. In other places, notably near the heads of some creeks where the gravels are shallow, unblanketed by muck, and well drained, the greatest part of the ground becomes thawed during the summer time.

Bench gravels are not common in the Fairbanks region. A deposit of gravels composed essentially of quartz-mica-schist, graphitic schist, and vein quartz has, however, been found in the valley slopes of Fairbanks Creek 600 feet above the valley floor. The gravel is rather well rounded and contains bowlders up to 1 foot in diameter. These gravels have been somewhat prospected, but, so far as known, without favorable results.

### FORMATION OF PLACERS.

It appears from a cursory examination that the pay gravels were deposited under conditions somewhat different from those which now prevail. Though the details can not be here discussed, some of the facts bearing on this matter deserve mention. The general uniformity in altitude of the ridges has been noted. This uniformity is the result of erosion when the region stood at a lower level than at present. Its topography then was that of an undulating surface dotted with rounded hills and broken by isolated groups of hills and ridges of greater prominence. The valleys furthermore were open and of low grade. It is probable that the stream deposits were deep and that there was much weathered bed rock in the interstream areas, awaiting transportation. Elevation of the region enabled the streams to cut the present valleys and thus form the avenues, or sluice boxes, as they might be called, through which passed the products of long-continued weathering as well as the deposits of the former streams. The bench deposits above described form a remnant of these old deposits.

In the constant, slow, and often interrupted progress of the unsorted coarse and fine material down the valleys the particles of gold, because of their high specific weight, tend to lag behind the particles of other materials and to find a lower position in the mass or a lodgment in the crevices of the bed rock. They offer a passive resistance to onward motion and an active assistance to downward motion in the vertical direction. The accumulating deposit of gold is mixed with unsorted material, which was probably, for the most part, not originally in association with the gold, but was derived from some source farther up the valley. This deposit will closely follow the cutting action of the stream in the bed rock and be the first to cover the bare surface of the latter when the opportunity offers.

Active erosion and an abundance of previously accumulated auriferous material appear to be the favorable conditions for the formation of placers. The so-called "wandering" placers which have been noted from Australia,[a] where the pay dirt is often shifted at times of melting snows to the claims lower down the valley, appear to represent an early stage in the development of placers. With the lessening of the stream's activity, accompanied often with the exhaustion of the great part of the auriferous material, the mobility of the deposits is diminished. There is then an increasing amount of barren material deposited over the pay gravels; there may be an abandonment by the stream of the part of the valley in which it has hitherto worked, and the pay streak becomes practically a stationary deposit. In the interior of Alaska the pay streak has become not only permanently stationary, but also, through the cementing agency of ice, for the most part permanently consolidated.

Few facts are known regarding the amount, distribution, or circulation of the underground waters and the consequent extent of the permanently or only temporarily unconsolidated gravels. There are valleys in the Yukon-Tanana country whose deposits are so "spotted," as it were, with live water that it is practically impossible to work them by drifting. The presence of large amounts of live water in many valleys during the winter is shown by the repeated overflows to which streams are subject and by the unexpected filling of prospect holes with water from below. It is possible, therefore, that the extent of the unfrozen ground is greater than is generally supposed. The extent of consolidation, while dependent primarily on the climate, is probable greatly modified by local conditions. The slope of the valley, the character and thickness of the deposits, and the quantity of water are factors which together may become of dominating importance, counteracting successfully the tendency of the climatic conditions to cause consolidation of deposits to great depths. As a result, a part of the deposits of a valley, be they talus or stream gravels, where these are not too deep, may retain a capacity for further differentiation. This, under the mobility imparted by the contained water and by the stream action to which they may be subjected, may bring about the gradual accumulation of the gold on or near the bed rock. In the Fairbanks region this process would be most active in the areas of shallow deposits, generally confined to the headwaters of the valleys. Although now there is not as large a quantity of weathered material at hand as formerly, when the product of long-continued weathering had accumulated, and although the proportion of gold may be different now from what it was formerly, nevertheless it is reasonable to suppose, and the occurrence of gold near the headwaters renders such a supposition entirely justifiable, that the deposition of auriferous material is there in progress. At the present time the streams come in closest relation, in the vertical section, to the bed rock near the heads of the valleys, and there, if anywhere within the valleys, downward cutting of the bed rock is in progress. The lower parts of the valleys have been areas of abundant deposition. Near the heads deposition closely follows cutting and there the deeply buried, more or less permanently frozen pay streaks of the lower valleys merge into the deposits within the zone of the present streams' activities.

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[a] Schmeisser, Karl, Die Goldfelder Australiens, p. 100.

The gravels in the valleys of the Fairbanks region are composed of materials derived from the bed rock in which the valleys have been cut, and were deposited through stream action, uninfluenced by any glaciation, yet under conditions somewhat different than those of the present. The position of the pay streak in a valley marks the position of an earlier drainage as well as that part of the cross section of the valley which was probably the deepest.

The successive stages of development may have been somewhat as follows: (1) Elevation of the region, the surface being laden with much unassorted weathered material and older stream deposits; (2) a period of active erosion by the streams, during which there was little opportunity for the formation of permanent deposits; (3) a period of deposition, when the streams were nearly down to grade and when the pay streaks were, for the most part, laid down with their clay content, which may have been derived in part from the abundant clay of the weathered material and in part directly from the bed rock; and (4) a period of stream shifting, valley widening, and further deposition, with the gradual development of the unsymmetrical type of valley of the present day. This unsymmetrical shape—one side steep and the other a more or less gradual slope—is a characteristic feature of many valleys in Alaska and results probably from several causes. It suffices here to mention only one of these, often observed by miners, that the sunny side of a valley is subject to more rapid wear than the shady side, which remains locked in frost for a much greater part of the open season. In the course of time there results an accumulation of waste which forces the stream toward the opposite slope of the valley.

The greater mobility of the material was due probably in part to the greater activity of the streams, which were at that time just becoming graded; in part to the more abundant precipitation, as is suggested by the much greater extension of the glaciers of the Alaska Range; and in part, perhaps, to a higher average temperature, though it would seem that, with the other factors present, no essential difference in the temperature would be required. Whatever the conditions of formation—and these are only imperfectly known—the dominant facts of economic importance are that in general but one pay streak has been laid down; that this is next to bed rock beneath a considerable thickness of other deposits, and that its formation is, for the most part, a closed incident.

## SOURCE OF THE GOLD.

The origin of the gold in the placers, while not definitely determined, is suggested by the character of the gold itself and by its association. Most of that found near the heads of the creeks is rough and practically unworn; much of it is flat, as if derived from small seams; most of the coarse pieces are intimately intergrown with quartz and are often flat like the small fragments of thin quartz seams which are common in the schists. That mineralization has not been confined to gold is shown by the occurrence of native bismuth intergrown with gold, of veins of stibnite, and of the cassiterite often found in the gravels. The most acidic igneous rocks observed in the Fairbanks region are intrusive porphyritic biotite-granites. The acidic dikes so common in the Fortymile region are absent, and the gold of the placers has probably been derived from small quartz seams in the schists.

It is often a subject of surprise to the miners that when gold is abundant in the placers it should be found so rarely in the bed rock. It might be said that if gold were commonly encountered in the bed rock the proportion of it in the placers, considering the amount of bed rock that has been removed, ought to be much greater. There is the possibility also that the veins in the country rock, which contributed the material for the first deposits of the valleys, were richer in gold than those now exposed. Be that as it may, it is certain that through long-continued weathering and sorting of the rock material a concentration of the heavier indestructible contents, including the gold, takes place, yielding auriferous detrital deposits which are made richer in gold than the parent rock.

## PLACERS.

### FAIRBANKS CREEK.

Fairbanks Creek is about 10 miles long and flows in an easterly direction to Fish Creek, a tributary of Little Chena River. The floor of its valley is 200 to 300 feet broad, but widens rapidly about 3 miles from the mouth. The productive area of Fairbanks Creek comprises about 4 miles of the valley, starting from a point about 2 miles below the source. The gravels usually vary from 25 to 40 feet in thickness, but in the lower part of the valley are much thicker. The pay streak ranges from 4 to 8 feet in thickness, averaging about 5½ feet, while in some places 2 to 3 feet additional of bed rock are mined. The pay streak ranges from 40 to 200 feet in width and in the upper part of the valley lies close to the present stream bed, but below it diverges toward the north valley slope. As it has not been traced through the lower part of the valley, it is uncertain whether it continues as a well-defined pay streak or becomes disseminated or distributed over a considerable area.

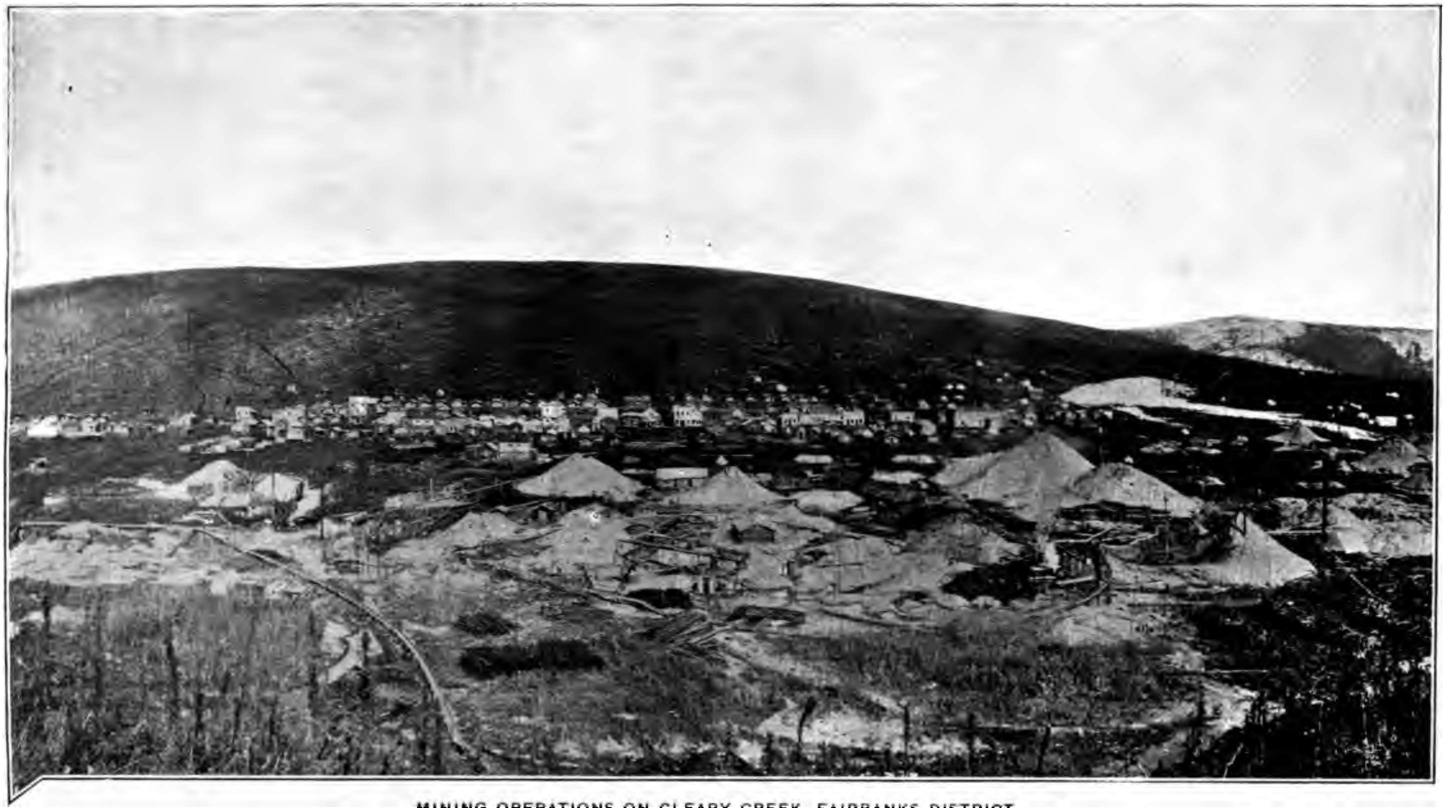
Fairbanks Creek has been a good producer, but the gold does not appear to be evenly distributed, and while much good ground is left, there should be careful prospecting to determine values before the introduction of expensive machinery. Several mining plants have been installed, some of which are finely equipped. The production of the past year has probably exceeded $1,000,000.

### PEDRO, GILMORE, AND GOLDSTREAM CREEKS.

Pedro Valley is similar in its general character to Fairbanks Valley. The productive area includes about 2 miles of the stream between the mouth of Twin Creek and the point where it is joined by Gilmore Creek. The deposits have a thickness ranging from 8 to 30 or more feet, and in some places values have been found through as much as 8 feet of gravel and 4 feet of bed rock, while in others they are confined almost exclusively to the bed rock. The distribution of the values has been found to be irregular.

Gilmore Creek, a tributary to Pedro Creek from the east, about 5 miles long, forks 3 miles above the mouth. The northern fork is called Tom Creek and the eastern fork retains the name Gilmore. The grade of Gilmore Creek below its junction with Tom Creek is about 100 feet to the mile, while above it averages about 300 feet to the mile. Some development work has been done in the upper part of the valley. The deposits in the Gilmore Valley are similar to those of the other valleys described, and range in thickness from a few feet in the upper part of the valley to about 60 feet near the mouth. Values have been found, but insufficient work has been done to determine their extent. The gold lies mostly on the surface of the bed rock or within it. Noteworthy features of the occurrence here are that the gold is reported to assay $19.25 to the ounce, the highest in the region, and that native bismuth is sometimes found intergrown with the gold.

Goldstream Creek is the continuation of Pedro Creek below Gilmore Creek. Here the valley widens and flattens and the deposits deepen, so that near the upper end there is a thickness of 30 to 40 feet of gravel. Though work has been done at intervals along several



MINING OPERATIONS ON CLEARY CREEK, FAIRBANKS DISTRICT.

miles of the creek, the output has as yet been small. The construction of the railroad, which parallels Goldstream Creek for several miles, renders it possible to mine lower-grade deposits than formerly, and considerable work was planned for the winter of 1905.

### CLEARY CREEK.

Cleary Creek, about 8 miles long, flows at first northwest and then, bending round gradually, follows a southwest course to Chatanika River. The two tributaries are Chatham and Wolf creeks, small streams which flow in short, narrow valleys and enter Cleary Creek from the east.

Cleary Creek has proved itself by far the best producer of the region. Workable deposits have been found along about 7 miles of the stream, and the limit of their extension into the Chatanika Flats has not been determined. Chatham Creek, only about a mile in length, has been a good producer. Considerable work was done on Wolf Creek two years ago, but since that time little gold has been found.

The deposits of the main valley range in thickness from a few feet to more than 120 feet, with an average of about 60 feet. The pay streak has a maximum thickness of about 14 feet and an average for the creek of about 5 feet. The width of the pay streak, under present mining costs, varies from 30 feet or less to several hundred feet, and in part of the valley is reported to be 800 feet. Though it is not yet well defined, the width will probably average at least 150 feet for the creek. The average value in the pay streak for much of the stream appears to be about $10 to the cubic yard. The pay streak is rather uniformly developed, but the width of the valley is such that its location requires much prospecting. The position of the pay streak in the valley is at variance with the course of the present stream. Above the bend the pay streak is altogether on the west side, several hundred feet from the creek, except at the head. It crosses the valley at the bend, and throughout the lower part is found on the right side 1,000 feet from the stream. As the valley of Cleary Creek opens to the Chatanika Flats, the pay streak swerves back to the left side and has been found there within a short distance of the creek. The pay streak may be said in general to occupy the center of the valley, being about equidistant, both above and below the bend, from the ridges on either side. The discovery of gold was made at the point where the pay streak crosses the valley, and there good surface prospects were found.

The important characteristics of the Cleary deposits are their thickness, the only shallow diggings being on Chatham and Wolf creeks and at the very head of Cleary Creek; the relation of the pay streak to the present course of the creek, and the extension of the pay throughout the lower part of the valley. The production for the last year has probably been about $4,500,000. While this figure does not possess a high degree of accuracy it serves at least to emphasize the fact that Cleary Creek has become an important producer.

### DOME CREEK.

Dome Creek, also a tributary of the Chatanika, is about 8 miles long and heads in the west side of Pedro Dome. The gravels of this creek are similar in character to those of Cleary Creek. Their thickness, so far as determined, ranges from 30 to 160 feet. Most of the mining has been limited to about 3 miles of the valley, commencing about 1 mile from its head. The known pay streak compares favorably in thickness, width, and values with those of other creeks, but its continuity has not been determined. There is a considerable area of mineralized rock on the slope of Pedro Dome and at the head of Dome Creek which is being prospected and is reported to carry values.

### ESTHER CREEK.

Esther Creek is tributary to Cripple Creek, a small stream that enters the slough about 3 miles above Chena. The railroad passes within 1½ miles of the creek and a wagon road with easy grades has been built to it along the birch-covered ridge which forms the northern limit of the valley.

Esther Creek is only about 5 miles long and flows in a nearly straight easterly course. The upper part of the valley is narrow; the lower part is open, shallow, and flat. A well-defined bench composed, so far as known, of fine sediment occurs on both sides of the upper part of the valley about 40 feet above the floor and appears to be recognizable in the lower part of the valley through the presence of remnants. The deposits are similar to those described, ranging from 25 to 90 feet and in one case to 135 feet in depth. A section of these last deposits from surface to bed rock is reported to be composed of 30 feet of muck, 80 feet of gravel, 14 feet of muck, 4 feet of clay containing some gold, and about 6 feet of barren gravel. An ancient beaver dam was found at a depth of 25 feet beneath the surface. On the next claim below this section the bed rock was found at a depth of only 90 feet. The cause of the difference in depth of the underlying surface is probably to be found in the difference of drainage conditions at the time the material was deposited. The search for gold on this creek should be guided not so much by the course of the present stream as by the position of known occurrences of gold, nor should it be assumed that the pay streak necessarily follows a line connecting two or more occurrences.

The creek is small, furnishing in the upper part of the productive area during the time of least rainfall less than half a sluice head of water, the grade of the valley is low, and the deposits are deep. Some excavations have been made at points scattered along about 3½ miles of the valley and, although these are insufficient to determine the continuity or average dimensions of the pay streak or its position in the valley, enough gold has been extracted to justify thorough exploitation and to establish the creek as a good producer.

## MINING METHODS.

The methods of mining in the Fairbanks region are the same as those used extensively for similar types of deposits in the Klondike region already described in detail by Purington.[a] Therefore only those points will here be set forth that illustrate most clearly the line of progress during the season of 1905. The methods have been necessarily determined by the grade of the valleys, the thickness and character of the deposits, and the available water supply. Only a small part of the ground has a grade of over 100 feet to the mile and most of it is considerably less. The deposits worked vary from a few feet to over 120 feet in thickness. The creeks are small, carrying ordinarily 200 to 400 miner's inches of water, although during the past season the abundant rainfall furnished enough water for all methods of mining. In dry seasons the present sources of water supply would be inadequate and, while thus far only short ditches have been in use, a project is under way to supply Cleary Creek with water from the upper part of the Chatanika Valley by means of a ditch about 35 miles long.

### PROSPECTING.

As it is an almost universal experience that the pay streak, if present, lies on bed rock, the chief work of prospecting consists in sinking holes to bed rock. Thawing the ground is usually necessary and, while the crude methods requiring wood fires, hot rocks, or hot water are still in use, the most approved method and the one most commonly employed is that carried on by means of steam, as described below. Small, portable, knockdown steam thawing outfits that can be packed on horses are now obtainable, thus permitting prospecting in remote areas. After the ice has been melted the material to be excavated is loosened with a pick, shoveled into a bucket, and hoisted to the surface, usually by hand windlasses. If the ground is deep the prospect shaft is generally timbered to the depth of the overlying muck. The most formidable difficulty encountered in sinking is live water, which often necessitates the abandonment of shafts. Great depth of ground also increases the difficulty of sinking holes and consequently makes the work of locating the pay streak slow. The method of prospecting by drilling has not been introduced in the Fairbanks region, but would probably find a place.

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[a] Purington, C. W., Methods and costs of gravel and placer mining in Alaska: Bull. U. S. Geol. Survey No. 263, 1905.

### OPEN-CUT MINING.

The ground is generally stripped first of all by sluicing off the overlying muck. A bedrock drain is then constructed, and an open cut of sufficient width for one or two sets of boxes is carried gradually up the valley. In some cases the gravel is hoisted by steam power entirely out of the cut to boxes set above the surface and to one side of the workings. By this method a frequent resetting of the boxes is avoided and there is a better disposal of tailings. Gravel is hoisted by derrick, by automatic trolley, or sometimes by a rock pump. When the last method is used a set of boxes is placed on the bottom of the cut, the coarsest pieces are forked out, and all the rest of the material is elevated through the pump to the boxes on the surface. Owing to the depth of the gravels, the open-cut method and its modifications are of limited application.

### DRIFTING.

The methods of working the deep gravels of this region may be said to be like those employed in the deep gravels of other fields, but with modifications rendered necessary by the frozen character of the ground. These methods have gradually developed in the Yukon territory and in Alaska and from year to year have become of increased efficiency in solving the problems that are met. In the Fairbanks region till within the last two years thawing was accomplished by the crude methods already mentioned, and the equipments for thawing by steam, which had been found so effective in the Klondike region, were not plentiful. Since then extensive steam plants have been introduced, capable of thawing and handling daily large quantities of gravel.

The process in general includes the following operations: (1) The sinking of a shaft to bed rock, ranging in depth from 20 to 120 or more feet; (2) the timbering of the shaft and the portion of the drifts near the shaft; (3) the opening up of the ground by drifts which are run either parallel to or across the pay streak and from which crosscuts are driven; (4) the extraction of the gravel from the crosscuts, beginning at the farther limits of the drifts and working toward the shaft; (5) the hoisting of the pay gravel with as little waste as possible to the surface, and (6) the recovery of the gold by ordinary sluicing. The main drift is usually carried to a maximum distance of about 200 feet in each direction from the shaft, and the ground is blocked off by crosscuts having a variable length up to about 100 feet. Fortunately, but little timbering is generally required. Where the ground is weak, pillars are left at intervals of about 25 feet when working back the faces. Ordinarily, as mining commences at the extreme limit of the area to be worked, the ground from which the pay dirt has been removed is allowed to settle if it will. Experience has shown that settling is generally so gradual that the work can be carried away from the settling ground with sufficient speed to avoid trouble.

The steam-point method of thawing is the one most commonly in use. The steam point is a piece of one-half or three-eighths inch hydraulic pipe, 5 to 8 feet or more in length, with a blunt, hollow point of tool steel for piercing the ground and a solid head of tool steel or machine steel, sufficiently strong to withstand the impact of a mallet or sledge. Steam is admitted through a pipe fitted laterally in a small aperture near the head. The points are placed about 2½ feet apart and from a dozen to twenty or more are used in a plant of average size. The power needed is 1 to 2 horsepower per point and the duty of a point is 3 to 4 or or more cubic yards per day of ten hours. In use the point is driven in gradually as the ground becomes thawed. It is customary in most cases to use either hot water at a temperature of about 140° F. or a mixture of hot water and steam while driving the points, and then to complete the thaw by means of steam alone, since by employing hot water in a part of the operation the atmosphere of the mine does not become so vitiated through the condensation of the steam and the conditions for working are consequently better.

Hot-water hydraulicking by means of the pulsometer or other steam pump has been found very successful in some cases. Pulsometers were in use which were reported to do the work of 20 points, and as by this method a jet of hot water is thrown forcefully against the frozen face, the conditions are more favorable for the release of the gold particles from adhesive material in which they may be embedded than by the use of points. Pulsometers are generally suspended in a sump at the bottom of the shaft and the hot water is supplied by siphon from the boiler. Surplus water is generally removed by centrifugal pumps. It seems probable that hot-water hydraulicking will meet with an increasing use.

After thawing, the gravel is removed with pick and shovel and carried by wheelbarrows to the shaft, whence it is hoisted to the surface by buckets attached generally to an automatic trolley. In summer it is conveyed directly to the sluice boxes, or, when water for sluicing is available for only part of the shift, to a hopper connected with the set of boxes. In winter the gravel is conveyed to a dump under which sets of boxes have been arranged and later, in the spring, it is passed through the sluices (Pl. XIII). Ground which stands well without timbering is worked both winter and summer, but summer work is cheaper. Ground having a tendency to cave is often left for winter exploitation, as it is found that the expense of rehandling in the spring is more than counterbalanced by the greater facility with which the gravel can be extracted.

The ordinary sluice boxes with pole riffles are universally employed, usually 12 by 14 inches in cross section. An average sized dump box or rock box is 20 to 22 feet in length and 36 to 40 inches or more in width. This catches from 60 to 90 per cent of all the gold saved and most of the remainder is caught in the next three boxes.

Ordinarily two clean-ups a week are made. The concentrates are dried in mining pans on stoves or blacksmith's forges and cleaned in most cases by dry panning and blowing. Every Saturday the treasure pack trains carry the week's production to town, where much of it is converted into bricks 4½ by 10½ by 2½ inches, containing 1,000 ounces, which are packed in boxes for shipment.

## COSTS.

The cost of mining under present conditions is such that ground worked must with few exceptions carry in the pay streak values of at least 2 cents to the pan, or approximately $2.75 to the cubic yard. Most of the claims are 1,500 feet in length, measured parallel with the courses of the creeks, and there are generally two or three outfits working on a single claim. In many cases the ground is worked by laymen, who give over from a third to a half of the output to the owners.

The prevailing wage for miners is $5 and board, but in some cases it reaches $6 and board per day. The duty per man per day of ten hours is from 75 to 100 wheelbarrows of dirt broken down with the pick, shoveled into a wheelbarrow or cars, and delivered to the shaft bucket; the average is probably about 9 cubic yards per day, but under very favorable conditions for short periods of time this quantity may be nearly doubled. The conditions under which work in the drifts is carried on vary with the character and form of the deposit. Where the pay streak is thin the drifts are made as low as possible, to avoid removing more waste than is absolutely necessary, from which it is seen that the most favorable conditions occur when the pay streak is of such a thickness, 6 feet or more, that on its removal there is space for perfect freedom of movement and efficient ventilation.

## SUMMARY.

While up to the present time the producing creeks are few and comparatively short and the deposits in most cases so deep and so consolidated by ice that machinery and much time are required for their development, the returns have been found for the most part satisfactory. The introduction of much machinery and an abundant rainfall have met with a quick response in a greatly increased production.

A most important question, and one most difficult to answer, is that of the capacity of the district for sustained production. It would seem that even the large output of last season, due largely to the unusual quantity of water available, could, with a continuance of similar conditions for a year or two at least, be maintained from the developed areas alone. There remains much undeveloped ground in the valleys which have furnished most of the gold, *equal in amount,* probably, to that which is being exploited. With the lower cost of mining resulting from increased facilities in transportation, there is the opportunity every season of working ground containing lower values; there are, further, the potentialities of the undeveloped creeks which have just become producers, and last of all, there are the possibilities of new discoveries. The region is not one where unusually large returns are to be expected, but one where energetic and intelligent operators may for a long time find a reward.

## SALCHA REGION.

The stream Salcha of some maps, from which this region takes its name, is known in Alaska as the Salchaket. The shorter form is, however, in accordance with the decision of the United States Board on Geographic Names. (See fig. 8.) During the last year considerable prospecting was done in this region, which lies 50 to 100 miles east of Fairbanks, adjacent to the north side of Tanana River. The area is drained by Healy, Volkmar, Goodpaster, Salcha, and Chena rivers and by several smaller streams, among which are Shaw, Tenderfoot, and Banner creeks. Most of the work has been done on Tenderfoot Creek, a small tributary of the Tanana, and on Butte and Caribou creeks, tributaries of the Salcha, streams whose valleys are all cut in schistose rocks.

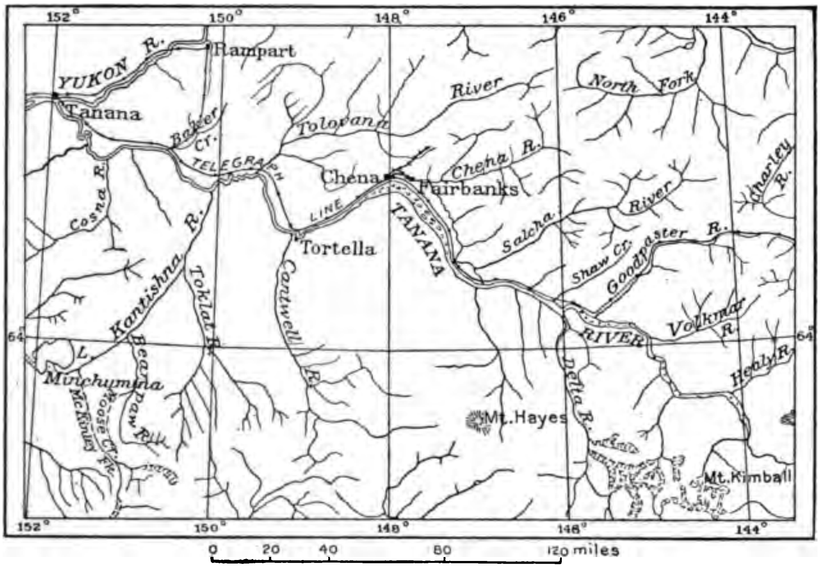

FIG. 8—Map of lower Tanana region.

The bed rock throughout this region consists essentially of schists, gneiss, and hornblende-granite. There is some greenstone and serpentine, which weathers brownish. The schists are like those of the Fairbanks and Birch Creek regions and include quartzite-schist, quartz-mica-schist, hornblende-schist, garnetiferous schist, and crystalline limestone in places garnetiferous. The gneisses are probably old granites that have been intruded in the schists.

The eastern extension of the schists of the Fairbanks region is a matter of economic interest. Though the schist belt is frequently interrupted by intrusive masses of granite of greater or less extent, it may be said in general that the valleys of Chena River and its tributaries are mostly in the schists, that a large part of the Salcha Valley is in the schists, and that to the east the schist belt gradually narrows and is confined to the lower parts of the valleys. The area between the Mosquito drainage and Healy River is mostly intrusive granite, granite-porphyry, and granite-gneiss, and the schists do not occur except along the lower parts of the valleys of Healy and Volkmar rivers. The rock of the Volkmar below the forks, so far as observed, is schist; above the forks, granite gneiss.

Tenderfoot Creek is tributary to the Tanana about 25 miles below the mouth of the Goodpaster. Transportation in summer is by steamer from Fairbanks to the mouth of Banner Creek, where there is a good landing and a road house, thence by pack train for a distance of about 3 miles to Tenderfoot Creek. The time required by steamer from Fairbanks to Banner Creek is three or four days. The freight rate for the season of 1905 was $80 per ton. The trail which follows the Government telegraph line from Fairbanks to the mouth of Goodpaster River is occasionally used, but it is very soft in places and frequently obstructed by the trees which have been felled.

Tenderfoot Creek is only about 6 miles long and carries probably not more than 3 or 4 sluice heads of water. It flows for a part of its course in a narrow channel in the muck, 15 to 20 feet below the valley floor, which is broad and has a grade of about 100 feet to the mile. There are remnants of a bench in parts of the valley just to the west of the creek and about 40 feet above it. The valley is filled with deposits ranging from 48 to 120 feet in thickness, of which the overlying muck makes up from 36 to 80 feet. The gravels are similar to those of the Fairbanks region, and comprise quartzite and mica schist, graphitic schist, feldspathic schist, and granite. At the time of the writer's visit several boilers were in use, a few holes had been sunk to bed rock, and in one case sluicing had been begun. Though a pay streak had been found, sufficient work had not been done to determine the value of the deposit.

Butte and Caribou creeks are adjacent westerly tributaries to Salcha River, joining it about 50 miles from its mouth. A combination road house and store and a military telegraph office are located at the mouth of the Salcha. Supplies were transported from Fairbanks to Butte and Caribou creeks during the last season largely by poling boats up Fairbanks Slough to the point where it leaves the Tanana, then up the main river for about 1½ miles, and finally up Salcha Slough and Salcha River. At low water it is possible to use a horse in towing boats for the greater part of the distance. At high water, however, the transportation is more difficult, for horses can not then be successfully employed. The time required from Fairbanks under the most favorable conditions is about seven days. The spur which starts at the head of Fairbanks Slough, near Mullowney's cabin, affords fair traveling for a pack train, and the distance to Butte Creek is about 40 miles.

A prominent ridge extends westward from the forks of Salcha River, about 60 miles above the mouth, dividing the drainage of the north fork from that of the main river below the forks and then swerves southwestward toward the Tanana between the Chena and Salcha drainages. The ridge has an undulatory outline with deep saddles and several points of prominence, of which the highest, known as the Butte, has an altitude of about 4,200 feet. The steep northern slope faces an open valley drained by Gold Run, a tributary of the north fork of the Salcha, which receives several minor tributaries from the slopes of the inclosing ridges. The southern slope is steep and is deeply cut by the headwaters of Butte Creek.

The prevailing rocks are schists, such as have been described as occurring in the Fairbanks region. Crystalline limestones are abundant in the hills east of the Butte and are in places thin bedded, alternating with schist, and, like schist, are frequently garnetiferous. Carbonaceous slates occur in the hills west of the Butte and here, too, is found considerable greenstone and serpentine. The Butte itself is composed mostly of a dark-colored intrusive granite. The gravels, so far as observed, are essentially the same in character and arrangement as those of the creeks in the Fairbanks region.

Butte Creek is about 12 miles long and is considerably larger than any of the productive streams in the Fairbanks region, carrying at the lowest stage during the last season 3 or 4 sluice heads of water. The valley has a grade of about 100 feet to the mile and a width in the middle of its course of about half a mile, but gradually becomes narrower toward the head, where it is joined by steep, narrow gulches. The creek flows for the greater part of its course near the east side of the valley, leaving on the west a flat of considerable extent.

It was not staked until the middle of May, 1905. The greatest part of the labor during the summer had necessarily been expended in providing shelter and supplies, and consequently when the stream was visited during the last week in August but little development work had been accomplished. Only three holes had been sunk to bed rock, but they disclosed a thickness of 24 to 26 feet of deposits which consisted of about 6 feet of muck and 18 to 20 feet of gravel. The gravels comprise several varieties of schist, gneiss, granite, greenstone, and vein quartz. Live water was encountered in some of the ground. Prospects were reported, but insufficient work had been done to determine whether a pay streak is present.

Caribou Creek, adjacent on the east, is about 7 miles long and carries less water than Butte Creek. The valley is narrow and deep. The position of the stream is close to the base of the high, steep ridge which forms the eastern limit of the valley. On the west side of the stream is a flat, in places a few hundred feet in width. The stage of development was found to be about the same as on Butte Creek, and many of the men who had been working there during the summer had just left for Fairbanks to get supplies for the winter. So far as could be learned gold was discovered in April, 1905. A few holes only had been sunk to bed rock. The thickness of deposits so far as developed ranges from 24 to 36 feet. The layer of muck was found generally to be but a few feet in thickness. Pay dirt has been reported and nuggets valued as high as $4.75. All that can be said regarding the future of the creek is that it is well worth prospecting. The creeks north of the Butte are also being prospected, and probably from 100 to 200 miners are working in this district during the present winter (1905-6).

## BONNERFIELD AND KANTISHNA REGIONS.

The country south of the Tanana, in the foothills of the Alaska Range, 50 miles or more southeast and south of Fairbanks, has been somewhat prospected. A rush of considerable proportions took place in the early spring to the valley of Little Delta River, and work has been continued in the Bonnerfield region, but thus far with no large results.

> The latest reports of placers in this field locate them in the vicinity of Mount McKinley. Several parties of prospectors ascended Kantishna River, a southwestern tributary of the Tanana about 100 miles from the Yukon. These men report the presence of auriferous placers in the Kantishna basin, near the foot of the mountains. The writer, who traversed this region in the summer of 1902, is unable to substantiate this report. Of the streams which flow into the Kuskokwim from the Alaska Range few, if any, carried even colors. In some of the streams of the Kantishna drainage system, however, some colors were found, and there was other evidence of mineralization. It seems at least possible that this field may yet produce placer gold.[a]

Kantishna River is a large tributary of the Tanana from the south about 160 miles below Fairbanks. (See map, fig. 8.) Toklat and Bearpaw rivers and McKinley Fork are tributaries of the Kantishna from the east. Moose Creek is said to flow into the Bearpaw from the west about 60 miles above the mouth. Gold has been found on the small headwater tributaries of Moose Creek and of Bearpaw River, streams 4 to 8 miles in length. Most of the steamers leave their supplies at the mouth of the Bearpaw, whence they are packed overland about 20 miles to the diggings, but a few have reached the mouth of Moose Creek. The rates for freight were $50 per ton; for passengers, $40 each; and the time required for the round trip from Fairbanks about two weeks. The reports indicate that the bed rock consists in part of schist, porphyry, and limestone; that the gravels, so far as worked are shallow, and that in some places, at least, they carry high values.

## FORTYMILE REGION.

The information here given regarding the Fortymile region is in part based on data gathered for the Survey by Mr. C. B. McDowell, of Chicken Creek, and in part on that gathered by the writer. The region has held its own with a production of approximately $200,000, most of which has come from Wade, Chicken, and Lost Chicken creeks. There were in the neighborhood of 400 people in the region, about half of whom were working on these three creeks. Other creeks where work was being done were Walker Fork, Franklin, Napoleon, Eagle, Mosquito Fork, Buckskin, Montana, North Fork, South Fork, and Fortymile Creek, and in the vicinity of the town of Eagle, American Creek, Discovery Fork, and Seventymile Creek.

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[a] Brooks, A. H., Placer mining in Alaska in 1903: Bull. U. S. Geol. Survey No. 225, 1904, p. 48.

The mining on Wade Creek is mostly open-cut work; that on Chicken and Lost Chicken creeks mostly steam drifting. No important discoveries were made during the year and no new methods were introduced. Developments have extended to the lower part of Wade Creek. There a steam hoist with automatic dump had been installed and a dam with automatic gate had been constructed, but at the time of visit, in July, there was insufficient water for effective use. At Lost Chicken Creek, too, an unwashed dump left from the winter's work bore witness to the lack of water. The water supply is often unequal to the demand in a dry season, and this fact can not be too carefully considered in the planning of an equipment, as otherwise an elaborate plant may be found well-nigh useless. The Fortymile region is at a disadvantage compared to some of the other districts because its remoteness from sources of supply makes the freight rates necessarily high and also because its supply point is on the Canadian side of the boundary, necessitating the payment of duties in addition to the high freight rates. Plans for utilizing the water supply of the larger streams by means of ditches have been under consideration, as have also plans for the introduction of dredges.

The gold-producing areas in the Fortymile region are many, and new discoveries of more or less importance will probably still be made. The district is, however, passing to the next stage of development and the main problem, one not easy to solve under present conditions, is that of handling large quantities of gravel at a low cost.

## BIRCH CREEK REGION.

The amount of gold sent out from the Birch Creek region during the year was about $300,000. The developments were confined mostly to Deadwood, Mastodon, and Eagle creeks. New discoveries were made on Switch Creek, a tributary of Deadwood Creek, and in the valley of Mastodon Creek, where the bench on the west was found in places to contain good pay.

There was considerable activity along the Yukon above Circle on small tributaries from the south, notably Woodchopper and Fourth of July creeks. The output for these two creeks was at least $15,000, most of which came from Woodchopper Creek.

## RAMPART REGION.

The statement regarding the Rampart region is based mostly on information furnished the Survey by Mr. H. F. Thumm, of Pioneer Creek. The production of the region for the winter season of 1904–5 and the summer of 1905 was approximately $200,000.

Some discoveries were made in the Baker Creek area, where pay gravels have been located at various points in the bench of Omega Creek over a distance of more than 2 miles, and in the bench of Pioneer Creek, where further discoveries have extended the limits of possible productivity from What Cheer Bar toward the head of the creek, a distance of about 5 miles. Ditches have been extended to the bench of Eureka Creek and a hydraulic elevator has been installed on Glenn Creek. In the Minook Creek area a large hydraulic plant was installed on Minook Creek and other plants were in the process of installation on Ruby and Hoosier creeks. So far as could be learned, little was accomplished by hydraulic mining during the last summer, not so much through lack of gold in the gravels as through lack of experienced management in the conduct of operations.

## KOYUKUK REGION.

The Koyukuk region, according to information received from Mr. Frank E. Howard, United States commissioner at Coldfoot, has produced approximately $200,000. About 130 men were engaged in mining and 28 claims were being worked. This mining field is at a disadvantage in comparison with others in the Yukon basin because of its isolation. Supplies after being landed at the mouth of the Koyukuk must be then transshipped to a smaller steamer, which ascends the river about 500 miles. From the head of navigation the supplies are taken to the producing creeks, 50 to 100 miles above, in poling boats during the summer and by dog teams in winter. The fact that mining continues under these adverse conditions bears testimony both to the richness of the deposits and to the determination of those who have developed them.

# RECONNAISSANCE FROM CIRCLE TO FORT HAMLIN.

By Ralph W. Stone.

## GENERAL STATEMENT.

Circle is at the upper end and Fort Hamlin at the lower end of Yukon Flats. (See map, Pl. II.) The distance between them is about 150 miles in an air-line, or 270 miles by river. In the summer of 1905 a topographic party under D. C. Witherspoon, accompanied by the writer as geologist, made a trip with a pack train between these two points, carrying topographic and geologic work as far west as the head of Hess Creek. The party entered the Crazy Mountains south of Circle late in June, traveled west across Preacher Creek to Beaver Creek, which was crossed at the mouth of Willow Creek, and thence north beyond Victoria Creek to Yukon Flats. From Mount Schwatka work was carried south into the White Mountains in the loop of Beaver Creek. Here early in September continuous snowstorms compelled the abandonment of both topographic and geologic surveys.

A United States Army expedition, led by First Lieut. Hjalmar Erickson, Seventh Infantry, explored this region in 1901, looking for a route for a proposed military road. A map of the drainage was prepared by William Yanert, who accompanied the expedition as topographer.

In 1904 L. M. Prindle and Frank L. Hess,[a] of the United States Geological Survey, went from Fairbanks northward across the head of Victoria Creek to Yukon Flats and thence down Hess Creek to Rampart.

## GEOGRAPHIC SKETCH.

The region described in this paper is an upland country lying west of the Fairbanks-Circle trail, bounded on the north by the Yukon Flats, on the west by the lower Ramparts of the Yukon, and on the south by the Yukon-Tanana divide. It is mountainous and ranges in elevation from about 700 to 5,000 feet. The Crazy Mountains, which lie at the east end of the area between Birch and Preacher creeks, trend northwest and have rounded rather than peaked summits, the highest of which is 3,690 feet in elevation. Between Preacher and Beaver creeks, and particularly in the great loop of Beaver Creek, the mountains are high and sharp crested. Elevations over 4,000 feet are common and the ridges are in places so steep and narrow that it is impossible to take horses along them. The White Mountains, around which Beaver Creek makes its big bend, are particularly rough and jagged. Between Beaver and Victoria creeks is a high ridge composed largely of limestone and granite and trending northeast parallel with the mountains on the south side of Beaver Creek. North of Victoria Creek a belt of limestone mountains having a northeast trend terminates abruptly at the Yukon Flats, falling off 2,500 feet Broad areas of comparatively level tundra country are found around the heads of Victoria and Hess creeks, and from that locality westward to Fort Hamlin the relief is moderately strong, the main streams being 1,000 to 1,500 feet below the ridges, which are for the most part gently rounded at the top, though the sides may in places be very steep.

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[a] Rampart gold placer region: Bull. U. S. Geol. Survey No. 280.

## DRAINAGE.

The drainage of this region is all tributary to the Yukon. Birch, Preacher, Beaver, and Hess creeks are the principal streams.

Birch Creek is the largest of these streams. It heads near Porcupine Dome, flows east, then north and west parallel with the Yukon for a hundred miles, emptying into the river about 25 miles below Fort Yukon. Over 80 miles of its course is across the flats. Albert Creek, a small tributary, drains the south side of the Crazy Mountains. At Twelvemile House, where the Fairbanks trail crosses the creek by ferry 15 miles from Circle, Birch Creek is about 180 feet wide and 10 feet deep. The discharge at a very low stage in June measured 1,579 second-feet.

Preacher Creek has its source at Rocky Mountain, opposite the head of Beaver Creek. It flows north and joins Birch Creek in the flats about 45 miles from the Yukon. At the west end of the Crazy Mountains, a few miles above the point where it enters the flats, this creek can be forded easily. Here for miles it meanders through a broad valley, its old courses being marked by oxbows and cut-offs.

Beaver Creek has been a puzzle to prospectors in previous years, but its upper course is now located. Rising at Rocky Mountain, it flows southwest for nearly 25 miles, then west 20 miles around the southwest end of the White Mountains and takes a northeasterly course to the Yukon Flats. Leaving the mountains, it flows north across the flats for 25 miles, then due west to the Yukon, into which it empties opposite the mouth of Hosiana River. The course of Beaver Creek across Yukon Flats, as of the other creeks, is very tortuous. Below the big bend where the creek comes through the limestone range fording places are not easy to find. The current is swift, and at many places horses can barely keep their feet in the deep water. Near the mouth of Willow Creek, a tributary from the southeast, a crossing was made 12 miles above the flats where the creek is 390 feet wide and from 1 to 2 feet deep. The discharge at this point was about 1,000 second-feet the first week in August.

Victoria Creek is about 25 miles long and heads against Hess Creek. The upper part of its course is through an open valley which has a much gentler southern than northern slope. In the lower course the valley is deep cut and narrow. Victoria Creek joins Beaver Creek just below the place where the two emerge from the mountains into the flats. In August the discharge, measured 11 miles above the mouth, was 467 second-feet.

Hess Creek rises northwest of the Beaver Creek loop and flows west for 75 miles or more to the Yukon, which it enters 25 miles above Rampart. This creek rises in a boggy country of low or moderate relief, and well up toward its head is so deep that horses have to swim.

A feature of the valleys of these creeks noted in several instances is their asymmetrical character. In some cases the left and in others the right side of the valley slopes much more gradually away from the stream. Beaver Creek, both above and below the big bend, crowds close against the mountains on the west, making a long southeast and a steep northwest slope. The same feature is marked in the upper part of Victoria Creek. Benching is conspicuous on these long slopes.

## VEGETATION.

A light growth of spruce timber is abundant in the valleys, with some willows along the streams. White birch grows in small patches at rare intervals. The timber line is about 2,000 feet above sea level. Good grass is not always obtainable. Caribou moss, however, is very abundant and large herds of caribou were seen in the Preacher-Beaver Creek region.

## GEOLOGY.

Although the geology of the region undoubtedly is complex in details, the general features are comparatively simple. A single formation of sedimentary rocks extends from the east end of the Crazy Mountains to the mouth of Hess Creek. It is intruded in three large areas by a mass of granite and interrupted by a narrow belt of older sedimentaries.

## STRATIFIED ROCKS.

The bed rock between Circle and Fort Hamlin is composed largely of slate, quartzite, chert, conglomerate, limestone, sandstone, tuff, and diabase. These have been grouped by Spurr into one formation, called the Rampart series,[a] and from fossils collected at various points are known to be of Devonian age.

The slates are for the most part black and seen only in patches of small chips along the ridges. Near the head of Willow Creek an outcrop of red and green slate was found, from which slabs nearly a foot square and an eighth of an inch thick could be procured.

Quartzite is common throughout the entire area and varies from typical gray quartzite with sugary fracture to cherty rock and to softer sandy beds.

Chert is a dense, siliceous rock of various colors, including black, gray, red, and green. Red and green cherts were found near Twelvemile House on Birch Creek, and gray cherts in the Crazy Mountains and on Willow Creek were seen folded and even strongly contorted.

Conglomerate in this region is composed mostly of chert pebbles. These vary from the size of buckshot to cobbles 6 inches in diameter. Small bands of sandstone and slate are found interbedded with the conglomerate. This rock occurs most abundantly in the Crazy Mountains.

Limestones of two distinct types are recognized here. One is white or gray, shows no distinguishable bedding whether fresh or weathered, and occurs in conspicuous projecting ledges. The other is gray to blue on the outside, dark blue on the inside, thin bedded, and strews the ground with small flat slabs. Limestone of the former type occurs in narrow belts in the Crazy Mountains. One belt not over 100 feet thick could be recognized for several miles by its prominent outcrops. The White Mountains in the big bend of Beaver Creek, a portion of the ridge between Beaver and Victoria creeks, and the mountains between Victoria Creek and Yukon Flats are largely of white limestone.

Sandstone and sandy shale constitute a small part of the formation and seem to be more abundant west of Beaver Creek than east of it.

Near the head of Victoria and Hess creeks, and close to the flats north of the head of Victoria Creek, soft black shales were seen which are probably of Carboniferous age. Prindle and Hess found the Rampart series extending from the head of Victoria Creek to the Yukon at Rampart.

Deep snow and continuous storm made it impossible to complete the traverse between the head of Hess Creek and Fort Hamlin, a distance of 60 miles; but from casual observations of quartzite, slate, sandstone, and diabasic and granitic intrusives the writer believes that the Rampart series forms the bed rock throughout the area.

The strike of the rocks through this whole region varies from N. 50 E. to east-west and is most commonly N. 65° E. From Birch Creek to Beaver Creek the structure consists of broad folds, but between Beaver Creek and Yukon Flats on the west the dip reverses at shorter intervals, and in the limestone range north of Victoria Creek is nearly vertical. The distance from crest to crest of the folds is several miles and the strata usually dip 30° to 40°.

## IGNEOUS ROCKS.

Tuffs and diabase appear frequently, associated with the stratified rock. A coarse-grained biotite-granite with pink feldspars an inch or more long occurs between the heads of Preacher and Beaver creeks. It forms all of Rocky Mountain, which is capped by a conspicuous castle-like ledge, and is abundant 8 or 10 miles east of Rocky Mountain, near the divide between Preacher and Birch creeks. This is the same kind of granite as that found by Prindle on Mastodon, Deadwood, and Portage creeks in the Birch Creek region. This granite outcrops in conspicuous ledges from 10 to 75 feet high and weathers to a coarse sand, making a marked contrast with the quartzite surfaces with which it is in contact. Granite also occurs abundantly above the junction of Victoria and Beaver creeks.

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[a] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, *pt. 3, 1898, p. 155.*

Intrusives, mostly diabase, are found in the Beaver Creek region, particularly on the divide between Beaver and the head of Victoria Creek. Quartz veins not over a foot thick were noted in a few places on the contact between sedimentary rocks and granite.

The only occurrence of schist noted was a few small pebbles of what appeared to be mica and quartzite-schist, found in the bed of Preacher Creek, mixed with large quantities of quartz, quartzite, and slate pebbles.

## PROSPECTING.

There were no prospectors in the region between Circle and Fort Hamlin in the summer of 1905. Choppings on Preacher Creek showed that men had been there, but if in search of gold, they must have met with little success. Preacher Creek is so called because a missionary at Fort Yukon showed gold obtained from a creek somewhere in that region about 1894, and prospectors, supposing this to be the one on which it was found, called the creek by its present name. In 1895 a few men took out some gold from Preacher Creek.[a]

Prospectors to the number of 100 or 200 visited Beaver and Victoria creeks in the summer of 1904, coming overland from Fairbanks and by boat from Circle. It is reported that gold was found in the stream gravels, but the colors were so few that no one was tempted to remain.

Willow Creek, a stream about 15 miles long, which joins Beaver from the south 10 miles above the point where it passes from the mountains into the flats, was staked along its upper course in August, 1904. Inscriptions on a tree indicated that there had been a small stampede, probably from the Fairbanks country, which had proved unprofitable. Some one seemed to have spent the winter on the creek and left in the spring of 1905. Bench gravels were seen 10 to 50 feet above the creek.

It seems to have been definitely determined that most of the gold placers in the Yukon-Tanana country occur where the bed rock is schist, that some of them occur where the bed rock is slate, and that all of them are in areas of more or less igneous intrusion. The gold probably occurs for the most part in small quartz stringers in these rocks. As there is no schist between Circle and Fort Hamlin, and as the region is not one of marked metamorphism, the conditions do not appear favorable for the occurrence of gold in quantities of economic importance. The unsuccessful prospecting seems to lend strength to this conclusion.

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[a] Spurr, op. cit., p. 119.

# GOLD MINING ON SEWARD PENINSULA.[a]

By Fred H. Moffit.

## INTRODUCTION.

The estimate of gold production on Seward Peninsula for the season of 1905, which has been given in a previous part of this report (p. 4), indicates a small increase over the production of the previous year. This increase has taken place in spite of adverse circumstances, chief among which are the unusually cold, wet summer, the early freeze-up, and the fact that some claims formerly rich have ceased to produce. Although the snows of the previous winter melted early in the spring, active work on the creeks began a little later than usual and ended when cold weather set in on September 18, in consequence of which the length of the open season was shortened by from two to three weeks, the largest part of the interruption coming at what is ordinarily the busiest time of the year.

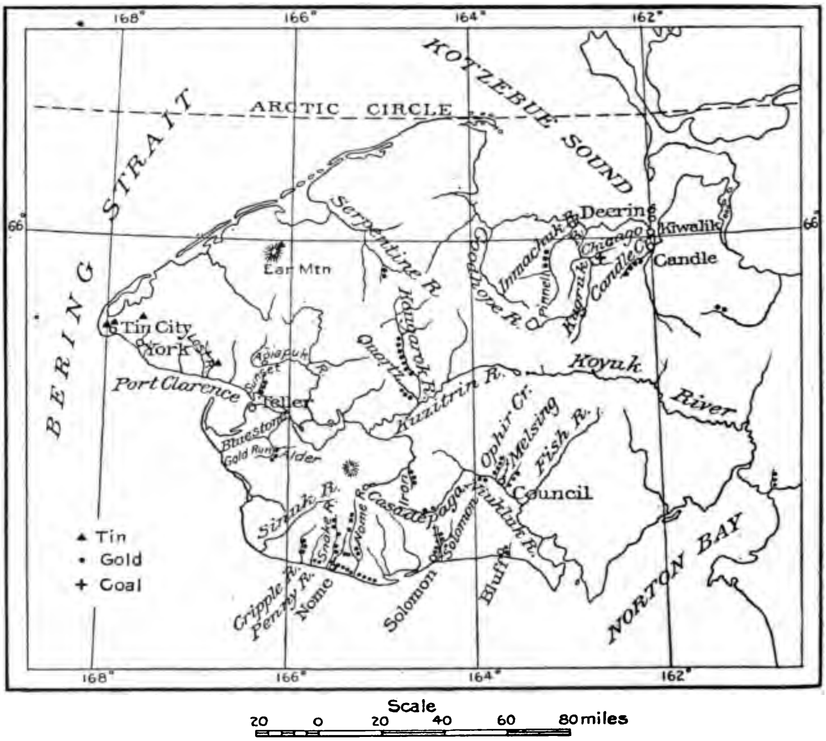

Fig. 9.—Sketch map of Seward Peninsula.

A decrease in production of the creeks, however, is not apparent from the figures given, since they include not only the summer output, but also that for the winter of 1904-5, which comes wholly from old beach and other deep gravels. From year to year the winter output has steadily risen, and that for 1904–5 would have shown a decided advance over that for the previous winter even if the remarkably rich gold deposits of Little Creek had not been discovered.

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[a] The facts presented in this paper were collected by Frank L. Hess and the writer during the field season of 1905.

As in previous years, the Nome region was the chief producer, after which should be mentioned the Council, Fairhaven, and Solomon River regions. (See map, fig. 9.) In the Kougarok, Teller, and Cripple River districts work during the summer was largely preparatory for coming years and took the form of ditch building. In fact, ditch building was actively prosecuted in all the placer-mining districts of the peninsula, but on the Kougarok; near Teller, and on Cripple River this kind of work was more in evidence than actual mining operations, a condition which did not exist in other places. On Ophir Creek and Solomon River the season was to a certain degree one of experimentation, a fact which contributed to the decreased output of those two regions. The four first-named localities, where mining and ditch building were both carried on, are therefore the more important contributors to the year's gold production.

## NOME REGION.

### OLD BEACH AND TUNDRA GRAVELS.

During the winter of 1904–5 a large number of holes were sunk along the line of the old beach between Nome and Hastings Creek and helped to determine more accurately the location and position of its pay gravels throughout the greater part of that distance, about 8½ miles. These pay gravels occur along the foot of a well-defined bench, which is continuous throughout much of the distance mentioned except where interrupted by some of the larger streams. The pay streak, as is well shown by the line of tents and cabins erected on the various claims where it occurs, forms an almost continuous deposit as regular in its direction as the present beach, to which it is nearly parallel and from which it is distant about two-thirds of a mile near Nome, but only one-third of a mile at Hastings Creek.

The gold-bearing gravels, which rest on a clay, or at times a gravel, "bed rock," have a thickness of from 3 or 4 inches to 2, rarely 3 or more, feet, and in probably most cases are reached at a distance of from 20 to 35 feet below the surface. On several claims the depth of pay gravels below the surface is about 40 feet, while in a number of cases they are less than 10 feet. The width varies from 25 to 100 feet, but averages from 35 to 40 feet, and at three widely separated localities the altitude above sea level is 37 feet. It has also been observed that the pay streak has a dip toward the south amounting in one instance to 4 or 5 feet in 50. In some places, such as Peluk Creek, Otter Creek, and Nome River, the gold-bearing gravels are less regular in their longitudinal extent and appear to have been cut through or scattered by the streams. On the other hand, it is possible that there may have been an indentation of the shore line at the mouths of these streams interrupting its regularity, although such is not the case along the present beach, the mouths of streams being characterized rather by delta deposits.

The gravels from which the gold is taken are true beach deposits, and, like the beach of to-day, contain a large amount of "ruby" sand and some marine shells. Broken walrus tusks and driftwood have been taken from various shafts.

Little is known regarding the continuation of the old beach west of Snake River. There is no gravel bench like that east of the river to mark its course, and few holes have been sunk to find it. Gold-bearing gravels were recently discovered near Jess Creek, a tributary of Penny River, however, which are probably part of its western extension. These gravels are at a distance of 1,200 feet from the present beach and resemble the deposits east of Nome in most particulars both as to composition and gold content. They lie at a distance of about 20 feet below the surface and extend in a direction parallel to the beach. Their discovery so soon after the clean-up on Little Creek led some to expect a repetition of the excitement following the discoveries of that locality, but when the season closed it had not yet been shown that they were any richer than the best of the old beach gravels between Nome and Hastings Creek.

The most productive claims in operation on Seward Peninsula during the past year were those on Little Creek, near the tracks of the Nome Arctic Railway, 3 miles north of Nome. They first came into prominence in the latter part of 1904 and have yielded since their discovery nearly $1,500,000. Much the larger part of the gold taken out came from four claims and from within an area little greater than one-tenth of a square mile.

The gold deposits are deep. The average depth of the various shafts is between 30 and 35 feet, but this is exceeded in a few instances and reaches 50 feet. A heavy covering of muck and moss, with a thickness varying at different places from 12 to 23 feet, overlies the gravel, and all is frozen from the moss down. The gravels are not entirely similar at all localities either in the thickness or character of the beds. Some are apparently well-washed beach sands, others were without doubt deposited by streams. At a distance of 1,000 or 1,200 feet east of the railroad track beach wash with a thickness of 5, possibly 7, feet—rests directly on bed rock (mica-schist) and is overlain by stream deposits. A short distance west of this the gravel lying on bed rock is probably of stream origin. Still farther west, near the railroad, thin beds of clean, rounded gravel are interstratified with stream wash. Beds containing bowlders up to a ton in weight overlie the workable gravels in some places and are a constant source of danger in mining, especially during the summer months, when the roof is weakened by thawing. These bowlders also occur on the bed rock and are found not infrequently in the muck overlying the gravels.

Nearly all the deposits from the surface to bed rock carry a certain amount of gold, but the rich gravels are found well down, in some places resting directly on the schist and in others at a height of 5 or 6 feet above it. The gold-bearing gravels of present economic importance have a thickness of between 4 and 5 feet, but in one instance where the material removed formed a lenticular mass the thickness was 16 feet. Thin elongated lenses or beds of reddish sand, called ruby sand, whose color is due in some cases to small grains of red garnet and in others to iron oxide, occur throughout the pay gravel and often contain enough gold to be easily seen, even when carelessly examined. Mica-schist, in which occur occasional thin limestone beds, forms the true bed rock, but the so-called "bed rock" on which the gold lies is in some places the schist, in others a clay streak, and in one place gravel cemented with calcite deposited by circulating waters. Part of the gold is fine, bright, and flaky; part is coarser, containing many nuggets of 5 and 10 cents, with occasional larger ones, some of which are valued as high as $20.

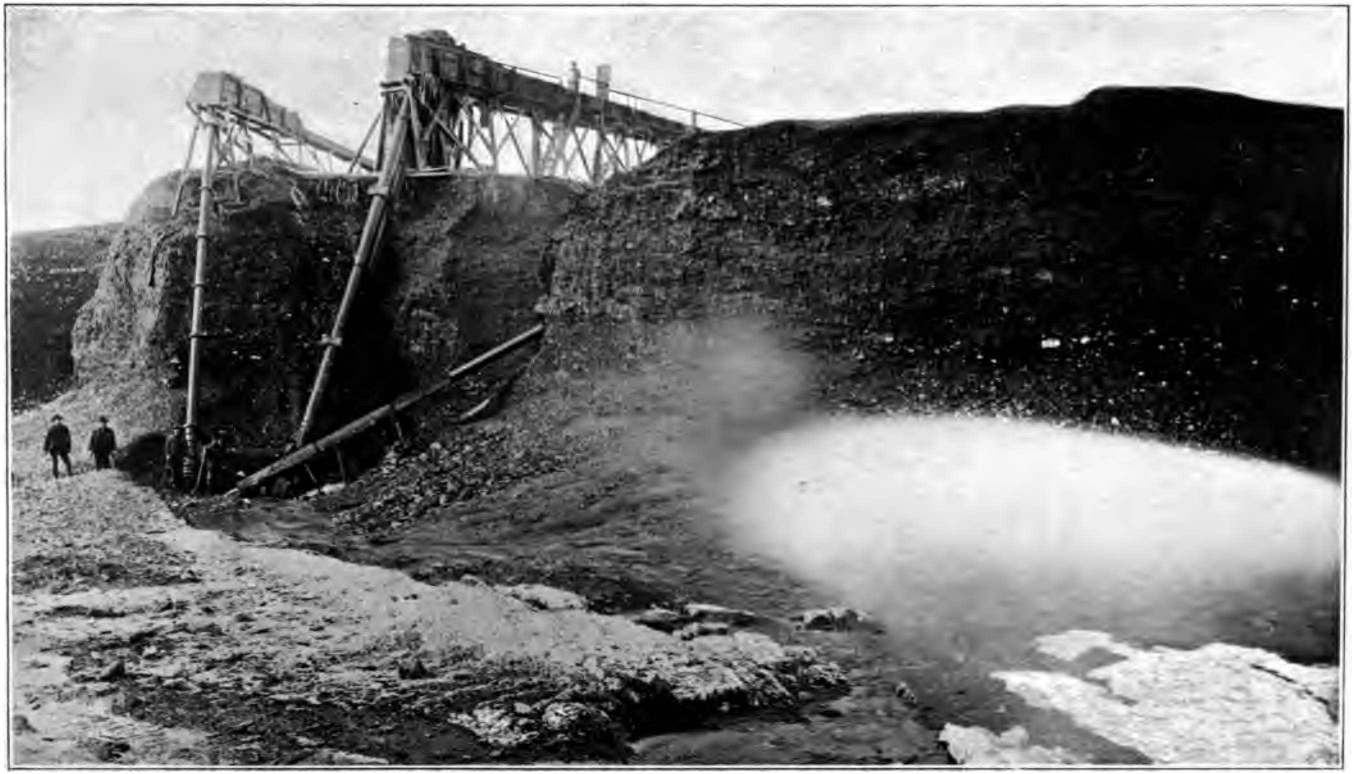
It seems probable that the lower gravel deposits at least were laid down in or near the delta of an ancient stream at a time when the shore line of Bering Sea was far north of its present location and that their position is due partly to stream action and partly to wave action. Abundant proof of the former presence of the sea only a mile to the south of Little Creek is furnished by the numerous marine shells thrown out on the waste dumps at different shafts.

One important result of the Little Creek discoveries is that they have led to more active prospecting in the tundra gravels. That a small amount of gold is almost always present in these gravels has been known for some time, but the occurrence and position of any other beach line back of Nome are matters which appear to be determinable only by sinking holes to find it. Undoubtedly the Nome tundra will be the scene of more extensive operations of this kind in the winter of 1905–6 than in any previous year of its history.

## STREAM AND BENCH GRAVELS.

There was little mining on any of the creeks of the Nome region till after July 1, and even then the weather conditions were exceedingly unfavorable, for cold southerly winds with dense fog and rain were continuous throughout the latter part of June and almost the entire month of July.

Glacier and Anvil creeks still continue to be the more important gold-producing streams *in the vicinity* of Nome, and while a large part of both has been worked out it is probable that



HYDRAULIC ELEVATOR ON GLACIER CREEK, SEWARD PENINSULA.

they will remain producers for some time to come. Mining on Glacier Creek proper is confined to the operations of the Miocene Ditch Company's hydraulic plant, a quarter of a mile below Snow Gulch, where two elevators are in use (Pl. XIV). On the bench north of Glacier Creek two hydraulic plants were at work. To the north Rock Creek was also a producer.

Anvil Creek is probably the most noted gold-producing stream in Alaska. It is the stream on which the first claims of the Nome region were staked, and since that time has always been in the first rank of producers. Discovery claim on Anvil Creek has already been worked over three times and the gravel on other claims has been moved twice. A force of men was employed during the summer on No. 7 above, but more extensive operations were carried on by the Pioneer Company on No. 5 above and the bench off No. 2 below and by the Wild Goose Company on Nos. 8 and 10 above. Mining was also done on two of the bench claims. On the upper part of Anvil Creek, at Specimen Gulch, the Miocene Company installed some large elevators, which are to be operated with water from their ditch.

There was little or no mining on Dexter Creek, formerly one of the large producers, but many of the smaller though well-known creeks, as Dry, Bourbon, Newton Gulch, and others, helped to make up the year's output.

During the summer two steam scrapers were installed on Nome beach—one at the east end of town, the other west of Snake River. They afford the first instance of the use of steam scrapers in handling gold-bearing gravels near Nome, and their adaptability for that purpose is of practical interest to all who are engaged in such work. It must be admitted, however, that the conditions under which they are used are different from those prevailing on the creeks, since they handle fine, loose gravels chiefly and are not required to clean a hard bed rock.

At the first locality, about 200 yards east of the Standard Oil Company's building, a 3-yard scraper is operated by a 75-horsepower logging engine with three drums, which secures a full control of the scraper from the engine. The scraper makes a trip in a minute and a half, digging a pit about 200 feet long and 100 feet broad at the wider end. The engine is on heavy skids and can be moved as desired. A sluice box 4 feet broad and 96 feet long, set 12 feet above the ground, is used, and water for sluicing is pumped from the sea with a gasoline engine. This plant was in operation during the latter part of the season, but that west of Snake River was not ready for work till late in the fall, so that little had been accomplished when cold weather set in.

Two dredges were in course of construction in the Nome region during the summer. One was launched in October at a point on Nome River east of "X" station of the Nome Arctic Railway and about 1¼ miles below Banner Creek. This is a large double-lift dredge and is ready to begin work as soon as the ground is thawed in the spring. The ladder, with its chain, the sump, and the pump are contained in one hull 115 feet in length, but the sluice boxes are built on a separate barge. All wearing parts, including the large centrifugal pump for elevating gravel from the sump to the sluice boxes, are of manganese steel. The ladder may be operated to a depth of about 30 feet. Crude oil is used for fuel and the dredge has a capacity of 3,000 yards per day. A hole was dug to bed rock before the freeze-up, but no mining was carried on.

The other dredge, of the dipper type, is being built on the sand spit at the mouth of Snake River and will not be completed till the coming season. It seems probable that dredging may take an important part in mining on Seward Peninsula in the near future and that it may help to solve some of the problems arising in the exploitation of the tundra gravels.

Two steam shovels were in operation on different properties on the east side of Nome River, near Irene Creek. They were equipped with tracks and cars for transporting gravel from the pits to sluice boxes and employed small locomotives to move the cars. As was the case on many other properties where new machinery was installed, the shovels were not in place till late in the summer, so that the season was a short one.

An account of ditch construction in the Nome region is given later (pp. 141–144).

## PENNY AND CRIPPLE RIVERS.

There was little mining on Penny River in 1905. To the west, in Cripple River Valley, work was carried on chiefly on Arctic, Nugget, Oregon, and Hungry creeks. There was also some prospecting on streams at the head of Cripple River, but the principal project was the construction of the Cedric ditch, which is described in another place (p. 142).

## IRON CREEK.

Much interest has been aroused during the past year by the developments on Iron Creek. This stream is a tributary of Kruzgamepa or Pilgrim River and joins it a little more than 10 miles below the outlet of Salmon Lake. The presence of gold has been known for some years and a moderate amount has been produced, but the cost of supplies has retarded development work. Mining is carried on almost entirely in the upper part of the creek valley, although some fine gold has been taken out below. On this part of the stream the gold is coarse. Nuggets of considerable size have been found, the largest of which, valued at about $650, was taken out last summer. Some difficulty is caused, on a number of the claims, at times of heavy rain by flooding, but a more general and serious difficulty is small water supply for sluicing. To remedy this condition one company had in course of construction during the summer four ditches, three of which are about 3 miles long and the fourth about 11 miles long. These will furnish about 500 inches of water when finished. The work was just fairly started when winter set in, but will be carried to completion next summer.

## SOLOMON RIVER.

### PLACER MINING.

The season of 1905 was not an important one on Solomon River because of its gold output, but attracts attention rather because in it a movement was started to supplant the methods in general use for handling gold-bearing gravels by others more economical in their operation and thus to reduce the cost of production and increase the amount of gold gained. Among the mechanical devices employed the most expensive and the most important from the standpoint of its capacity is the new dredge launched on Solomon River at Oro Fino, 5 miles north of Solomon. This fine dredge (Pl. I, p. 1) is of the Bucyrus type and was completed about the middle of summer. The gravels here are not of great depth and while the deepest excavation yet necessary was but 23 feet, the elevator can be operated to a depth of 28 feet below the water's level. There are 66 buckets in the chain, each with a capacity of 6 cubic feet and weighing 1,150 pounds, the total weight of chain and ladder being 149,000 pounds. The buckets are required to elevate not only the gravels, but about 1 foot of the mica-schist bed rock—an important matter, since on its ability to do so may depend the success of the dredge. Neither dredge nor steam scraper will clean a hard limestone bed rock. The power used is steam, but the machinery is so constructed that electricity may be substituted at slight cost and with little loss of time. At present the greatest item of expense is coal, since the entire plant requires but three men for its operation. It is proposed, however, to decrease the expense by using electric power, generated either by water or possibly at the beach, where fuel is less expensive owing to decreased freight charges.

The gravels to be exploited were thoroughly prospected, before the dredge was built, with a traction drill which proved itself well adapted to the purpose.

About the middle of summer a steam shovel was installed on the first tier of benches west of Solomon River. Practically no work was expended on pay gravels during the few weeks after the machinery was put in place, that time being devoted to the construction of a bed-rock drain, but the plant is ready to be put in operation as soon as the ground is ready in the spring.

Gravel is loaded on cars of 2½ yards capacity by a 1-yard dipper and drawn up a low incline by a small hoisting engine to a platform, where it is dumped at the head of the sluice boxes.

A stream of water, assisted by a man at the platform, carries the gravel into the boxes. Empty cars run down the incline to a short switch, from which they pass to the main track below the loading cars and are ready to be filled again, the average time for a round trip being about three minutes. It was found that the hoisting engine used was small and that some difficulties arose, owing to the manner in which the track was laid, but these difficulties can readily be overcome. Water for sluicing is brought through a 3-mile ditch from Shovel Creek and delivered at an elevation of 27 feet above the boxes.

An experiment which is of no small importance in a country where a supply of water under sufficient head is difficult to obtain, and which is of especial interest since several undertakings of a similar nature have not been successful, was being made on Solomon River last summer, namely, the pumping of water for hydraulic purposes. The plant is located a short distance above the steam shovel just mentioned. The pump is of the three-step centrifugal type, driven by a three-cylinder gasoline engine of 225 horsepower. The engine stands on a cribwork of heavy timbers set in the ground and filled in with concrete, making a solid foundation. A firm foundation is an absolute necessity for the success of such heavy machinery and was not obtained until after several attempts had been made, for the frozen ground beneath thawed, leaving the engine on a bed of water-filled gravels.

The pump delivers, on an average, 280 inches of water with a head of 140 to 150 feet, which is divided between the giant and the hydraulic elevator, the larger part going to the elevator. With the present setting water is carried horizontally a distance of 700 or 800 feet to the pit and elevates the gravel to a height of 15 feet. An elevator with 8½-inch throat and 16-inch upcast is used.

The engine requires 250 gallons of oil per day, costing 17.5 cents per gallon, and the plant is operated by a force of six men. Considerable time was lost through delays caused by the engine or elevator, but the interruptions were largely done away with before the season closed.

Elsewhere on Solomon River and its tributaries the mining methods employed are hydraulicking with the aid of hydraulic elevators, pick and shovel work, and in one case scraping with horse scrapers.

North of Solomon River there was some work on streams flowing into the Casadepaga, chiefly on Ruby, Willow, and Penelope creeks.

### QUARTZ MINING.

Numerous quartz veins, many of which carry small amounts of gold, have been found in various parts of Seward Peninsula and scores of quartz claims have been staked, but the Big Hurrah mine, on the creek of that name flowing into Solomon River 11 miles above Solomon, is the only occurrence of this kind which is being successfully exploited. The ore occurs as free gold in quartz veins in a hard siliceous graphitic schist. There appears to be little or no pyrite present, but some iron stain is seen on the quartz. Development work has gone steadily forward until the force of men now supplies ore to 20 stamps. An indication of the confidence which the owners have in their property appears in the fact that considerable new machinery was recently installed

## COUNCIL REGION.

The Council region during the summer of 1905 has also been the scene of several experiments whose object is to supplant old methods of handling gold-bearing gravel by cheaper and more efficient ones.

The Wild Goose Company has been and still is the chief advocate in this region of the use of hydraulic elevators for this purpose. Its efforts have been directed largely toward perfecting the operation of the elevator and especially toward securing a large and permanent water supply which can be depended on in all seasons. This has been accomplished by the completion of a ditch, as described later (p. 143). The company also makes use of the derrick system on one claim, but most of the tailings are removed by hydraulic elevators.

A pumping plant for hydraulic mining similar to that on Solomon River was erected on Ophir Creek during the early part of the season. It differs from the one on Solomon River chiefly in the power of the engine, since the machinery is of the same kind in both cases. This engine is of 150 horsepower, weighs 25 tons, and uses oil from Bakersfield, Cal., as fuel, the average cost of oil being 32 cents per gallon including the price of tanks. No difficulty was encountered in securing a firm foundation for the machinery, since it rests on the solid rock. Two hundred and fifty inches of water with a head varying from 120 to 130 feet are divided between the giant of 1½-inch nozzle and an elevator of 2-inch discharge. The elevator has an 8-inch throat and a 15-inch upcast which was found to be too large and was reduced by inserting a 12-inch pipe. A small nozzle on a canvas hose is used to ground sluice off the muck before the giant is employed. Gravel is elevated 20 feet and it is said that under favorable circumstances 750 yards can be moved in a day.

At two localities on Ophir Creek trials of steam scrapers for moving gravel have been made and while the scrapers have not been operated at a profit in either case, owing to insufficient power, lack of proper equipment, and inexperience in handling, the results are such that a more extensive use will be made of them another year. Many of the difficulties to be overcome have been learned and it is believed by those who have made the experiments that the experience gained last summer will enable them to secure machinery adapted to the conditions and to operate it successfully.

In the first case a 2½-yard scraper was used. Power was furnished by a gasoline engine and the scraper was handled by two steel cables running over 18-inch sheaves. The tail rope passed through a shift block moved by a small steam winch, thus obtaining a lateral movement for the scraper. A pit 270 feet long, 75 feet wide at one end and 10 feet wide at the other was dug and the mica-schist bed rock taken up to a depth of 1½ feet A round trip required about three minutes, but the average amount of gravel moved each time varied from 1¾ yards to 2 yards. The gravels were pulled up a short, steep incline and dumped into the sluice boxes. The gasoline engine in use was found to be poorly adapted to the work, since the strains on it were not sufficiently uniform to give good results.

On the second claim where a steam scraper was employed much of the equipment made use of was originally intended for other purposes. A scraper with a capacity of 1½ yards and weighing 2,700 pounds was operated by steel cables from an engine of 25 horsepower. The shift block was moved by a small hand winch and two men. The fuel used was crude oil and was expensive because of the great expense of freighting—$22.50 per ton—on Niukluk River from Cheenik to Ophir Creek, to which must be added the cost of freighting to the claim from the river. Three hundred yards of gravel were put through the boxes per day, but the scraper was found to realize little over 50 per cent of its theoretical capacity. Six men, including a man at the tailings pile, were required to handle the plant. During the coming season it is proposed to install a more powerful engine and larger scraper, dumping directly into sluice boxes, which will be set lower than the present line of boxes. A small scraper will then be required to keep the lower end of the boxes free from tailings.

Shoveling into sluice boxes, the incline and car system, and horse scrapers are the only other methods by which gold is won on Ophir Creek, except near its lower end, where the De Soto dredge is at work. This dredge was used first on Niukluk River below Council Creek in 1903, then moved up the river, and finally, in the spring of 1905, was placed on Ophir Creek, this being accomplished by digging a short canal across the narrow neck of land separating the river from the creek near the place where the creek leaves the hills to cross the river flats. The dredge works on a spud and can be moved in 2½ feet of water. It handles about 1,500 yards per day, taking up from 2 to 6 inches of bed rock. Wood is used as fuel and costs about $8 per cord, but the price varies at different seasons of the year.

Besides the work on Ophir Creek and its branches—Sweetcake Creek, Dutch Creek and its tributary, Snowball Creek, and Crooked Creek—mining was carried on in the Council region on Warm, Goldbottom, Elkhorn, and Camp creeks, all tributaries of Niukluk River.

The only winter mining was that on Snowball Creek. In connection with the gold deposits of Ophir Creek it may be said that the occurrence of cinnabar in quartz veins on Crooked Creek has been known for several years and that gold amalgam is found in the gravels there.

South of Council, on Melsing Creek, a small steam shovel was employed during the summer to strip off the overburden from pay gravels about a mile east of Niukluk River. The gravels here have a thickness of from 3 to 4 feet and the muck above about the same. The gold lies on bed rock, which it penetrates to a depth of 2 feet in some places. Muck and gravel were first removed by the scraper to within 6 inches of bed rock, when the remaining gravel and as much of the bed rock as was necessary were taken up by hand and shoveled into sluice boxes. A small scraper holding two-thirds of a yard was operated by four lines, three of which were attached to the scraper and the fourth to a shift block. Much annoying delay was caused by the lines, owing in part, doubtless, to the use of sheaves of too small diameter and failure to keep the ropes and sheaves free from sand Pits of 100 or 110 feet by 50 feet were dug and the gravels dumped at one side out of the way, the time required for one round trip varying from two and a half to three minutes. Power was furnished by a small steam engine. Wood was used as fuel under the boiler. Only 1¼ cords were required per day, but this cost $13 per cord, since no provision for fuel had been made the previous winter, and it had to be hauled in summer when wages were higher and freighting more difficult.

Other operators on Melsing Creek either make use of the horse scraper, as is done near the mouth of Basin Creek, or shovel directly into sluice boxes.

## DANIELS CREEK.

Daniels Creek continues to be an important producer of gold, and with the water supply available since the enlargement of the Topkok ditch should increase its output during the coming year. An interesting fact in connection with the melting of Daniels Creek gold is its loss in weight due to the volatilization of cinnabar caught in the sluice boxes with the gold. The cinnabar occurs in the creek gravels, but is not known in the beach sands to the south.

## TELLER REGION.

The gold output from the region adjacent to Teller comes almost entirely from two creeks, Gold Run and Bering Creek. Of these, Gold Run is by far the larger producer, the gold being taken from claims located just above the mouth of Alder Creek. Mining on Bering Creek was almost entirely restricted to the bench gravels. The gold is coarse, bright, and unworn, and it is said that 75 per cent of it is picked up by hand.

On the Arctic slope, southeast of Shishmaref Inlet, ten men were prospecting on Dick Creek, a tributary of Serpentine River. A copper prospect also has been discovered in this region. It is located near the head of South Fork of Serpentine River, between Quartz and Bismarck creeks. The copper occurs as carbonates, chiefly malachite with some azurite, with quartz, at a [illegible] of limestone overlying gray mica-schist. A shaft 25 feet deep has been sunk ab[illegible]in, which dips to the northwest, but it must be carried down 20 or 25 feet farther before reaching the ore. An incline 20 feet long was also driven in the vein, whose thickness is said to be from 6 to 21 inches, and 10 to 12 tons of ore were taken out, which will be sledded to Teller this winter (1905–6).

## KOUGAROK RIVER.

No member of the Geological Survey visited any part of the Kougarok or the Fairhaven precinct in 1905. Development work on Kougarok River consisted largely of ditch construction, but the gold output of the whole region is not small compared with the other regions except Nome and Ophir Creek. Aside from Dick Creek, Kougarok River is at present the most difficult placer region of Seward Peninsula to reach, and the exploitation of its gold-bearing gravels has been greatly hindered by the heavy cost of provisions and other supplies. These, until the past summer, have usually been carried by boat from Teller through Grantley Harbor and Imuruk Basin and up Kuzitrin River to Lanes Landing, thence overland by wagon to the various camps, including those on Dahl Creek and the tributaries of Kougarok River. During the summer of 1905, however, when much more freight was carried into the country than during any previous season, many of the boats were taken up Mary River to the recently constructed warehouses at Davidsons Landing and there unloaded. Wagons were then employed to transport it over a new trail to the upper part of Kougarok River. Much of the mining on Kougarok River has been of a most primitive kind, often done with a rocker, but with ditches now completed or in course of construction it will be possible to reduce the cost of handling gravels materially. Mining has been restricted chiefly to the upper part of the stream above its forks, except on Quartz Creek and a number of its tributaries, which, although the gold has been obtained at very great expense, owing to the character of the ground and the low grade of the streams, have thus far been the most productive creeks of the region.

## FAIRHAVEN PRECINCT.

In the Fairhaven precinct during the last summer and previous winter interest has been centered on Candle Creek, yet development of the Inmachuk has gone steadily forward and some prospecting has been carried on in Kugruk River Valley.

### CANDLE CREEK.

Candle Creek was first known through its remarkably rich creek gravels, which were vigorously exploited during the first two years after the discovery of gold. After these rich deposits had been largely worked out the camp suffered a rapid decline until in 1904 its fortunes were at their lowest mark. Those whose confidence in the creek was not shaken, however, turned their attention to the benches west of the creek, where gold-bearing gravels were finally located, and during the winter of 1904–5 produced a large amount of gold. Although Candle Creek is regarded as a winter camp and the creek claims have been said to be worked out, the creek turned out nearly half the total product of this locality for 1905. Pay is said to have been found in the bench gravels as high as the third tier of claims west of the creek. The deposits are all frozen and coal for generating steam to supply the steam points is obtained from Chicago Creek, a tributary of Kugruk River. This coal (see p. 141) is a lignite, and while much inferior to Wellington coal can now be furnished so cheaply as to compete with the latter. Candle Creek will probably be a more active camp during the winter of 1905–6 than any other on the peninsula with the exception of Nome.

### INMACHUK RIVER.

The more productive claims on Inmachuk River are located within the first 6 miles of the valley below Pinnell River. The valley is here broad and flat, the river meandering widely and departing farther and farther from a direct line as it approaches the sea. Aside from the river itself two tributaries have produced small amounts of gold, Hannum Creek and Pinnell River, including its branch, Old Glory [illegible] on whose greatest production was during the first two years after its discovery. Miniphir Creek [illegible] River has not been attended with much success, although gold-bearing gravels are found immediately below its mouth on Inmachuk River. Development work on the Inmachuk has shown that the pay streak does not always follow the present stream course, but that in several instances it runs into the gravels on the west side. This is what might be expected when one studies the topography and sees the numerous old, partially filled meanders of the valley. The operations of the last year have been principally the exploitation of gold-bearing gravels whose location was already known, but have also resulted in extending the northerly limit of these gravels some distance farther down the river. Mining in the gravels of Inmachuk River and of Candle Creek also is attended with more embarrassments than on the south coast of Seward Peninsula. The difficulties arise from several adverse conditions, first among which are the low gradient of the streams and the present lack of water for mining purposes, together with the shortness of the mining season and the cost and difficulty of obtaining all kinds of supplies.

Chicago Creek coal is coming more and more into use as the cost of mining it diminishes. It is expected that the consumption of this coal will be greater during the winter of 1905–6 than in the preceding one, since new machinery has been installed and greater efforts are being made to place it on the local market. As has previously been stated in a bulletin of the Survey,[a] this coal is a lignite and occurs in isolated areas at several localities on the eastern side of Seward Peninsula. The rocks associated with it outcrop along Kugruk River below Chicago Creek and also above it for a number of miles, but have been folded extensively, and since they possess the same north-south strike as the schists on either side of the river are not apt to attract attention unless one looks for them. In the summer of 1903 the writer made a hasty trip to Chicago Creek and went up Kugruk River to the mouth of Independence Creek. Coal was frequently found on the river bars and was present in sufficient quantity to be used for fuel. It has not yet been determined in what amount the coal is present in this valley, but its character is such that it can never have more than a local market. Nevertheless, the two camps on Candle Creek and Inmachuk River are fortunate in having such a supply at hand if, as has been said, it can be delivered at a cost of $16 per ton.

## DITCHES.

Ditch construction formed so prominent a feature in the development of the placer districts of Seward Peninsula in 1905 that an account of what has been done merits a separate treatment. Small ditches carrying 1 or 2 sluice heads of water have always formed a part of the necessary equipment of almost every claim. Such ditches usually take their water supply from the creek on which the claims are situated, the water having no greater head than is required to deliver it at the upper end of a line of sluice boxes. The ditches now being constructed are not of this kind, but are intended rather to deliver large amounts of water with the greatest possible head and are frequently of considerable length, such as the Miocene ditch, which with its various branches measures more than 50 miles.

During the summer of 1905 there were either completed or in course of construction on Seward Peninsula not less than 13 ditches, each with a capacity greater than 1,200 miner's inches, over half of them carrying 2,000 inches or more. While these ditches are all within drainage areas tributary to Bering Sea, they are not confined to any one locality, but are distributed among the various mining regions of the south and central parts of the peninsula. Several large ditches have been built in former years, but in this account attention will be given chiefly to ditches in course of construction during the summer of 1905.

The Seward ditch takes its water from Nome River 800 feet below the mouth of Dorothy Creek, and will deliver it to the tundra claims south of Newton and Anvil creeks. Its total length will be 37 miles, of which about 30 are now completed. For the first 3½ miles below the intake it measures 14 feet on the bottom, 22 feet on the top, and has a 5-foot bank. All rockwork is of the same width. With a depth of 3 feet this ditch will carry 4,100 inches of water. The remaining excavation is but 10 feet across the bottom, the intention being to widen it later. This is said to be the general practice in ditch construction on Seward Peninsula; they are not originally dug of full width, but widen through the thawing and sloughing in of the sides. At two localities piping was required—an inverted siphon of 40-inch pipe 820 feet long over Hobson Creek, and an inverted siphon 615 feet long over Clara Creek. The ditch has a grade of 3.17 to 3.18 feet per mile and delivers water at its lower end at an elevation of about 400 feet above sea level.

The Pioneer Company is constructing a ditch to carry water from Nome River to the south side of Anvil Mountain. This ditch is about 60 feet lower than the Seward ditch, and is smaller, being 8 feet across the bottom and having a 3-foot bank. Work on it was begun in the middle of the summer and about 8 miles were constructed before the season closed.

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[a] Moffit, Fred H. The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, p. 67.

The Penny River ditch has its intake on Penny River one-half mile above the mouth of Willow Creek and has a length of about 6 miles. It ends on the tundra one-fourth mile north of the beach and one-half mile from the mouth of Jess Creek. The tundra portion has a width of 15 feet and a depth of 1 foot, but is expected to increase to a width of 20 feet and a depth of 2 feet. It has a grade of 3.12 feet per mile, and is intended when enlarged to its full size to carry 3,000 inches of water. Very little ice was encountered in the course of construction and no pipe or flume was necessary, so that the cost of the ditch was unusually low.

A second ditch was built on Penny River by the Pioneer Mining Company. It has a length of 11 miles and is intended to carry 1,500 inches of water. It begins one-fourth mile above Little Nugget Creek and ends at Sunset Creek at a point 250 feet above Snake River. The width on the bottom is 7 feet, the depth 3 feet, and the grade per mile 4.22 feet. No solid rock and very little ice were met, but 2,200 feet of pipe line were required.

The Cedric ditch, in the Cripple River drainage basin, was constructed under unusually adverse conditions. It is 24 miles long and has a capacity of 2,700 miner's inches, though not more than 1,800 inches have been run through it yet. It heads on Josie Creek and will collect water for more than 20 miles along the line, supplying it to Oregon, Trilby, and Arctic creeks, at which latter stream it ends. Fifteen miles were constructed in limestone and 15,000 yards of canvas were used in making the ditch tight. The canvas was sewed together, seven widths wide, and laid on the bottom of the ditch, being weighted and sodded to hold it in place. An inverted siphon of 38-inch pipe 2,800 feet long was required to carry the water over Oregon Creek, where a head of 235 feet is available.

The Independent ditch, on Osborn Creek, has its intake on Eldorado Creek 1,400 feet above the mouth and crosses Bonita Creek, from which water is also taken, 900 feet above its mouth. Continuing down the west slope of Osborn Creek is crosses Willow Creek and has been advanced to a point three-fourths mile below that stream. When completed it will have a length of about 9 miles and will furnish water with a head of 210 feet. The width of the bottom is 14 to 16 feet and the height of its lower bank 3 feet, giving a capacity of 2,500 inches. No ice or frost has been encountered so far and there is no rockwork.

The Flambeau-Hastings Ditch and Mining Company has constructed 4½ miles of ditch, beginning at the upper fork of Flambeau River and continuing south along the west bank of the stream. When completed this ditch will have a length of 29 miles and a capacity of 2,000 miner's inches. The water, taken from various streams which the ditch crosses, will be conducted through a long pipe line across St. Michael Creek to the south side of Osborn or Army Mountain and thence south and east to Hastings Creek.

The Solomon River Ditch Company constructed a ditch 6¾ miles long, on Coal Creek in 1905. Its intake is about 5 miles above where the ditch now ends at the mouth of Coal Creek, and a head of 240 feet is available for mining purposes. It is proposed to carry this water south along the east side of Solomon River to East Fork. This ditch makes the fourth large ditch in the Solomon River region, three others having been built previously. These include the French ditch, carrying water down the west side of the river from John Creek to East Fork; the McDermott ditch of the Solomon River Hydraulic Company, which carries water along the south side of East Fork to a point about a mile below its mouth; and a ditch 8½ miles long on Big Hurrah Creek, belonging to the Midnight Sun Mining and Ditch Company and carrying water to Solomon River.

The Moonlight ditch, north of Solomon River across the divide on the Casadepaga side, 1 mile of which was constructed in 1904, was lengthened by 4,000 feet last year. This ditch has its intake on Moonlight Creek one-fourth mile above Arctic Creek and receives much the greater part of its water from large springs in the limestone. It is proposed to extend the ditch down the Casadepaga to Dixon Creek, which would give it a length of about 22 miles.

The Topkok Ditch Company, at Bluff, now owns 35 miles of ditch, having added 12 miles to the old ditch begun in 1902. The original ditch was 21 miles long, had its intake at the forks of Klokerblok River, and ended at the penstock one-half mile from the beach at Bluff. The portion of the ditch built in 1905 takes water from Skookum Creek at the mouth of Boil Creek, where 1,500 inches are obtained from the three branches. It has a width across the bottom of 5½ feet, a 3-foot bank, and a grade of 5.28 feet per mile. There are 5,000 feet of piping, of 30- and 28-inch pipe which permitted it to be nested in shipment. This is capable of withstanding a pressure of 150 pounds. Nearly a quarter of a mile of tunnel was driven to shorten the ditch line.

Much the larger part of Ophir Creek is controlled by the Wild Goose Mining and Trading Company, and to work its claims this company has constructed the largest ditch on Seward Peninsula. To the 40 miles or so of ditch in use in 1904 11½ miles were added in 1905. The intake is located on Pargon River, on the north side of Chauik Mountain, but the water of Helen Creek is also taken and the supply thus obtained is conducted along the east and south slopes of the mountain until it can be discharged into the upper tributaries of Ophir Creek, to be taken up again in the old ditch below. The ditch has a width of 10 feet on the bottom, 16 to 18 feet on the top, and a grade of 4.22 feet per mile. It is said to have capacity of 6,000 inches. More than 13,000 feet of fluming were required to carry the water over unfavorable ground. With the present ditch system the water supply is made constant and a material decrease in the cost of mining will be possible.

The ditch known as the "Sunset ditch" is being built by the Arctic Mining and Trading Company to supply water for hydraulic purposes on Sunset Creek, which flows into Grantley Harbor 3 miles northeast of Teller. Work was begun in July, 1904, and 15 miles were completed at the end of that season, 16 miles being added in the summer of 1905. Water is taken from Agiapuk River, but another branch 7 miles long will be constructed to tap California River and provide an additional supply. Most of the ditch has been made to carry 1,500 inches, but this will be increased to 2,000 inches. The water is delivered on Sunset Creek 1½ miles above the mouth, and has at that place a head of 212 feet. An inverted siphon 3,800 feet long across Mountain Creek saves the construction of 7 additional miles of ditch, while 3 miles around Shellman Creek are saved by a similar pipe line 1,800 feet long. In the first case 36-inch pipe reducing to 24-inch was used, in the second 36-inch pipe reducing to 22-inch. A large portion of the ditch is in limestone, and some difficulty was experienced with ice, one of the most serious obstacles ditching has to contend with in Alaska.

In the Kougarok country a ditch is being built by a company of which Mr. J. M. Davidson, one of the three originators of the Miocene ditch of Nome, is president. It takes water from Kougarok River 3½ miles above Macklin Creek, opposite the mouth of Mascot Creek, and follows the left bank of the river. When completed the ditch will extend as far south as Arctic Creek, a total length of 12½ miles. More than 7 miles, from the intake to Homestake Creek, were constructed in 1905, and work will be resumed in the spring. With a width of from 8 to 9 feet on the bottom, a 2½-foot bank, and a grade varying from 4.22 feet per mile in the upper 3½ miles, to 3.12 feet in the remainder of the portion now built, the ditch will carry about 2,000 inches of water, but its capacity will later be increased to 2,500 inches. About 1 mile of rock work in close-grained schists and slates was necessary, but so far only 1,000 feet of ice have been encountered—along the south side of Macklin Creek. This stream is crossed by an inverted siphon 843 feet long made of 32-inch and 30-inch pipe and with a depression of 53.6 feet at its lowest point. Another inverted siphon 1,000 feet long using 36-, 34-, 32-, and 30-inch pipe is required at Goose Creek. As has been suggested, the use of pipe of different diameters arises from the decrease in freight charges, since space is saved by nesting the pipe. A third pipe line 2,376 feet long, with a dip of 150 feet, will carry the water over Taylor Creek when the ditch is extended. At the present terminal opposite Homestake Creek a head of 160 feet is available.

A second large ditch now in course of construction in the Kougarok country is known as the North Star ditch. Its intake is located on Taylor Creek 1¼ miles above Midnight Creek. It follows the north bank of Taylor Creek to Kougarok River, where, after crossing

Taylor Creek, it continues south along the east slope of the Kougarok to Arctic Creek, a distance of 15.2 miles. The ditch measures 8 and 9 feet across the bottom, its banks have a height of 4 feet, a grade of 3.8 feet per mile is maintained in its earth and rock portions, and its capacity is 4,000 inches. Four thousand cubic yards of rock have been excavated, and 600 feet of fluming, 6 feet wide and 3 feet high, with a grade of 7.7 feet per mile, are required on bad ground. There are also 2,600 feet of 40-inch piping, which is riveted throughout, there being no slip joints. The piping crosses Taylor Creek one-half mile above Rock Creek, where it will be supported by cables of 1¾-inch wire rope passing over piers on either side of the channel and forming a suspension bridge with a span of 100 feet. All the materials used in construction, after being shipped from Teller to Davidsons Landing by water, were freighted overland to the Kougarok, a distance of about 40 miles.

# THE YORK TIN REGION.

By Frank L. Hess.

## INTRODUCTION.

During the year 1905 the York region has remained the only part of Alaska giving promise of producing tin in commercial quantities. The region has been visited and briefly described a number of times by members of the United States Geological Survey,[a] but as it is has continued to attract the attention of the mining public it has seemed desirable to supplement the previous observations. During the months of August and September the writer spent several days at each of the known tin-bearing localities except those on Ears Mountain.

The York region, in a general way, may be defined as a triangular area with its apex at Cape Prince of Wales, in longitude about 188° 5′ west, from which point it extends eastward to about longitude 166° west. It is bounded on the north by the Arctic Ocean and on the south by Bering Sea and Port Clarence. The settlement called Tin City is situated on Bering Sea about 5 miles from Cape Prince of Wales. Buck Creek is about 14 miles and Ears Mountain about 55 miles east of the cape. The Lost River deposits are about 25 miles, and York, a collection of a few cabins at the mouth of Anikovik River, about 10 miles southeast of Tin City.

From Nome, the center of population, trade, and mining in the peninsula, boats sail at frequent intervals during the open season to the mouth of Lost River, York, and Tin City, while boats going to Kotzebue Sound will land persons who wish to reach Ears Mountain from the Arctic coast side, at Shishmaref Inlet.

## TOPOGRAPHY.

Between the York Mountains on the east and Cape Mountain on the west there is a table-land rising to an elevation of about 600 feet. This table-land, known as the York Plateau, is an old marine bench which is now dissected by streams and above which occasional hills rise higher than the general level. A remnant of this table-land runs down the coast to the east, forming a narrow bench, a mile or more wide, as far as California River.

East of the York Plateau are the York Mountains, steep sided and sharp ridged, composed largely of limestone and frequently almost bare of vegetation. They reach their summit in Brooks Mountain, 2,918 feet high, about 5 miles north of the head of Lost River. Through these mountains the streams have cut their channels to comparatively low grades. About 16 miles north of York, Potato Mountain rises to 1,370 feet, while to the west Cape Mountain, an isolated mass with steep sides and cliffs of granite exposed to the wash of Bering Sea and Strait, reaches 2,300 feet. It, too, shows remnants of the York Plateau, with a well-marked bench at about 300 feet elevation, above which are long level shoulders, probably remnants of another bench, at a height (barometric) of about 1,300 feet. At the south side of the mountain the alluvial fan of a small stream has been eaten away until a bank 30 to 40 feet high is exposed at the shore. The nearer streams on the east have sand bars across their mouths and the lower ends of their valleys are occupied by lagoons. These facts seem to indicate that a subsidence of the land in this neighborhood is going on at the present time.

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[a] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: special pub. U. S. Geol. Survey, 1901, pp. 136-137. Collier, A. J., Tin deposits of the York region, Alaska: Bull. U. S. Geol. Survey No. 225, 1904, pp. 154-167; Recent development of Alaskan tin deposits: Bull. U. S. Geol Survey No. 259, 1905, pp. 120-127.

Along the Arctic shore there is a broad, low tundra with fringing sand spits, behind which are shallow lagoons, the largest of which is Lopp Lagoon. Over the flat, or tundra, are scattered almost innumerable ponds and lakelets. From the shore the land gradually rises to the hills from 6 to 16 miles back.

The streams of this watershed are the longest of the region, but their grade is low and their course across the flats is tortuous.

## GEOLOGY.

### SEDIMENTARY ROCKS.

In a general way the rocks run across the York region in broad north-south bands, intruded by greenstones, granites, and some more basic rocks. East of a line running approximately northeast from the mouth of Kanauguk River to the Arctic plain the great mass of rocks is of limestone, generally thin bedded, which seems to be of Upper Silurian age and is known as the Port Clarence limestone. Between York Creek and Mint River is a large area of slates, of unknown age, in the south end of which is Brooks Mountain. A smaller area of slate lies between California and Don rivers.

West of the limestone is an area of sedimentary rocks varying from graphitic slate to fine-grained false-bedded quartzite. In places, particularly north of Potato Mountain, the rock has been jointed into pencil-shaped rhombohedral fragments. Its age is unknown, and so far it has not been definitely correlated with the patches of slate to the east. This slate extends from the Kanauguk to a point about 5 miles east of Tin City, where it is succeeded by a limestone of Carboniferous age, apparently overlying the slate.

### IGNEOUS ROCKS.

Cape Mountain is a mass of coarse gray porphyritic granite thrust through the limestone, and into the latter acidic dikes and sills have been intruded in all directions. There are also later basic dikes cutting both limestone and granite. The upper 400 to 450 feet of the mountain are composed of a dark, fine-grained quartz-sericite schist, whose bedding seems to be about flat. Between the schist and the granite is a bed of limestone 10 to 12 feet thick.

On the north of Potato Mountain there are a number of granite dikes with others of a somewhat more basic character.

At Brooks Mountain, Ears Mountain, and Tin Creek are large intrusions of granite, while granitic dikes cut across Lost River valley at many places and are also found on King River and in the slate area between Don and California rivers.

Greenstone dikes, probably altered diorites or still more basic rocks, cut the slates at a number of places in the vicinity of York, and basalt or diabase dikes are known on Cape Mountain and along Lost River.

### ALLUVIAL DEPOSITS.

The alluvial deposits are generally shallow, 5 or 6 feet being ordinarily the maximum depth of the stream gravels. The depth of the gravels of the Arctic tundra is unknown.

## TIN DEPOSITS.

### LODES.

#### LOST RIVER AREA.

The first discovery of lode tin in Alaska was made in the summer of 1903 on Cassiterite Creek, a tributary of Lost River, about 7 miles from the sea, by Messrs. Leslie Crim, Charles Randt, and W. J. O'Brien. The place was visited by Arthur J. Collier and the writer immediately afterwards, and the occurrence was described by Collier.[a] A small amount of prospecting was done that year, enough to show that the tin ore occurred in a much metamorphosed acidic dike. The property was bonded, but reverted to the owners the next year (1904). During 1904 and 1905 prospecting continued, several more dikes carrying cassiterite were found, and several veins in the limestone were discovered.

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[a] Collier, A. J., The tin deposits of the York region, Alaska: Bull. U. S. Geol. Survey No. 229, 1904, pp. 17-23.

Should the lode deposits be shown to carry sufficient values to pay for exploitation, they will have many advantages over placer deposits, for they can be operated the entire year, while placer deposits can be worked only during the short open season and even then there are frequent delays and inconveniences from storms, floods, lack of water, freezes, and other hindrances. Lode mining, being under cover, can be carried on without regard to weather.

### GEOLOGY.

The entire Lost River basin lies within the Port Clarence limestone. About a mile from Lost River, on Tin Creek (a tributary of Lost River, 5½ miles from the sea), is a large boss of granite, half a mile in diameter and 1,000 feet high. Many acidic dikes cut the limestone, radiating in a general way from this boss, though but few can be traced directly to it. The dikes are usually but a few feet wide, 18 inches to 25 feet being the approximate limits, with local widening or narrowing. Acidic dikes, having no apparent connection with this complex, but with a character lithologically similar, cross the basin at other points. Near the coast are several dikes of diabase. The acidic dikes are probably of several ages and some contain none of the darker minerals and are of rather uniform texture, while others contain porphyritic orthoclase and quartz, resembling the granite of Cape Mountain. The dikes cut the limestone without reference to its bedding and the joint planes of the limestone sometimes extend across the dikes.

Close to the granite boss on Tin Creek, and near the dike in which tin was first discovered on Cassiterite Creek, portions of the limestone have been so metamorphosed that they would ordinarily be hardly recognized as such. The portion changed is from 1 to 3 or 4 feet wide, and takes a serpentine course through the unaltered limestone, with no apparent regard for bedding or jointing. The altered portion has a general green appearance and in places a weathered or polished face looks like an intensely crumpled schist, while in other places it is a mass of metamorphic minerals—epidote, vesuvianite, hornblende, calcite, fluorite, brown, red, and other garnets, quartz, magnetite, pyrite, and probably other minerals.

### ORE BODIES.

At the time of the writer's visit (September 10–13, 1905) the only known deposits of cassiterite were on the Crim, Randt, and O'Brien group of claims, and one other, Discovery claim, on a dike known as the Dolcoath lode.

The Crim, Randt, and O'Brien deposits include those originally discovered and several veins and tin-bearing dikes found since. The original discovery was on a rhyolitic dike, called the Cassiterite lode, running from Cassiterite Creek across the mountain eastward to Tin Creek, a distance of about a mile. Developments to the end of the season of 1904 were described by Collier as follows: [a]

> A tunnel and a crosscut show an ore body about 60 feet long by 15 feet wide, the lateral walls of which are the well-defined contacts of the original dike matter with the limestone. The dike rock in this shoot has been altered mainly to kaolin, though the original texture is partially preserved. Cassiterite in fine grains is rather uniformly distributed through this mass, but it is reported that the tin content dropped below 1 per cent at the end of the tunnel.
>
> A second tunnel, driven on the dike about 200 feet east and 200 feet higher on the hill, shows the porphyry in a less kaolinized condition. Here it still contains some tin ore, although in smaller amounts. Samples taken from the croppings of the dike several hundred feet farther east were said to contain traces only of tin.
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> The attempts to trace the dike westward were unsuccessful, though several prospect holes were sunk in the line of its extension west of the 60-foot tunnel noted above, seeming to indicate that the dike ends near this tunnel.

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[a] Collier, A. J., Recent development of Alaskan tin deposits: Bull. U. S. Geol. Survey No. 259, 1905, pp. 121-122.

During the summer of 1905 a tunnel was run into the hill somewhat lower than the lowest of the prospect tunnels referred to by Collier and about 80 feet above the creek. In this the dike was again found and is said to carry tin. Owing to water in the tunnel work was suspended until the freeze up, and the dike had not been crosscut at the time of the writer's visit.

By stripping the débris, 3 to 10 feet thick, another dike, or a branch of the one described above, was uncovered about 100 feet to the south. The dike was laid bare to a width of 25 feet, but its full thickness was not reached. The rock is much decomposed, but as it is frozen its removal requires much drilling and the use of dynamite. Drilling in such rock is easy, but, like frozen ground, it is "short" in blasting and picking is slow and tedious. The dike is of the same rhyolitic character as the one in which the original discovery was made and contains inclusions of a darker intrusive, also much decomposed.

Several small tin-bearing veins were found in the dikes, varying in width from 1 to 2 inches, and occasionally widening out to form vugs almost entirely filled with beautiful dark cassiterite crystals embedded in fluorspar and zinnwaldite (a lithia-iron mica). The vein matter is largely zinnwaldite and the only enlargement seen by the writer was apparently about 2 feet in diameter and probably at the crossing of two veins. The strike seemed to be between north and west, with a rather flat northeasterly dip. The fluorite with the cassiterite is white. Some wolframite is found in the tin veins, though in small amounts. A few feet south of the tin veins there are two small veins of molybdenite, one-fourth inch to 1½ inches thick. The molybdenite is in masses of small scales accompanied by fluorite and a mica in peculiar wedge-shaped forms whose largest sides are about one-half inch across. Over these wedge-shaped forms the mica sometimes has a vermiculate appearance, from small plates standing at a right angle to the edges of the larger individuals. In color it varies from a light greenish yellow to a waxy lemon-yellow (specimen T5AH99 and others). No tin was seen in these veins. The fluorite is purple and green, a small amount being colorless, while in the tin-bearing veins it is practically all colorless, so far as seen in the limited examinations. It is generally granular, but little occurring in large crystals or masses.

The first vein filling seems to have been largely replaced by other minerals. In one specimen (T5AH98) of mixed mica and fluorspar, containing a small amount of molybdenite, are a number of cavities, the largest of which is nearly 1 inch across and 2 inches long, having the hexagonal form and terminations of quartz crystals. In these cavities are small cubical crystals of colorless fluorite and some yellow mica, while a few black spots, probably of pyrolusite (manganese dioxide), stain the surface of both mica and fluorite. From this specimen it appears that the vein was originally lined with combs of quartz crystals, after which the fluorite and mica were deposited, and later the molybdenite. There was little deposition after the removal of the quartz. The manganic stains probably come from waters percolating through the limestone, as small veins of pyrolusite occur in a number of places. The size to which the quartz crystals grew would seem to show that the deposition of the other minerals took place a long while after the intrusion of the rhyolite.

A prospect cut in the bank of the creek exposed the same dike carrying a small amount of tin. A stream-cut bench in the dike 3 to 4 feet above the present creek bed, covered with 3 feet of gravel overlain by about 8 feet of débris, was also exposed. The gravel carries angular crystals of cassiterite and from the ease with which it can be handled would probably pay for working in a small way. To judge by the contour of the surface, the gravel deposit appears to be a quarter of a mile long and 50 feet wide.

A dike known as the Ida Bell lode is on the west side of Cassiterite Creek just above the Cassiterite lode, and is believed by the owners to be an extension of the latter, although to the writer this does not seem proved. Instead of being one dike it is really three that have come up through the same fracture. The middle 5 or 6 feet of the mass is a white rhyolite with quartz phenocrysts partially resorbed, while on each side is a smaller dike from 2 to 3 feet wide of a badly decomposed gray granitic rock with porphyritic feldspars. The dikes strike N. 50° W., with a vertical dip. A tunnel has been run about 100 feet along the east side of the dike, with a crosscut about 50 feet from the mouth. Some tin is found along a horizontal fault zone on the east side of the dikes and more is said to have been found at the end of the tunnel. Quartz veins an inch or less wide, carrying wolframite and probably some tin, occur in a silicified portion of the dike about 66 feet wide, 50 feet from the mouth of the adit.

About 500 feet north of the Ida Bell lode is another dike of rhyolite, which resembles that of the Cassiterite lode, and is called the Bear lode. It has an east-west strike, and on top of the hill between Cassiterite Creek and Lost River is about 35 feet broad. A tunnel about 55 feet long was run into it from the creek level and a winze sunk 69 feet along the west or hanging wall. This was filled with water, so that it could not be entered. It was said that many small tin-bearing veins were found running in various directions, most of which were near the middle of the dike. Fragments of rock in the dump showed veins of almost pure cassiterite and quartz about one-half inch thick and other veins carrying cassiterite, chlorite, and some wolframite up to 1½ inches thick (specimens T5AH82, T5AH83, and others).

At the creek level the dike is much decomposed and considerably iron stained. Where exposed on the top of the hill it is hard and shows no tin. About 275 feet to the north, along the top of the hill, there is a similar dike, 6 feet wide, striking N. 60° W. No tin has yet been found in it. It is noticeable that no tourmaline has been found in these deposits.

The Dolcoath lode is a narrow dike about 2½ feet wide, 1 mile N. 15° E. of the Cassiterite lode. It strikes N. 70° E. and dips 65° NW. A crosscut on the Discovery claim showed the dike to be about 2½ feet thick. On the hanging wall is a deposit of arsenical and antimonial pyrites mixed with feldspar, from 6 to 12 inches thick. The feldspar carries some cassiterite, which also occurs in calcite and impregnates the limestone (specimens T5AH72 to T5AH75). Topaz in incomplete crystals one-half inch broad accompanies the cassiterite. The feldspar is of a light pinkish-gray color, and would be supposed to be merely vein matter were it not that 400 feet to the east, along what seems to be the same dike, the dike matter has been entirely changed and shows only light-colored orthoclase-feldspar, quartz, and tourmaline, so that what seems here to be a vein may be the feathering out of a second dike in the same fracture. In places in the limestone on the foot-wall side of the dike cassiterite forms a vein 4 or 5 inches thick. There are signs of faulting in the veins and joint planes run from the limestone across the dike. An assay of the feldspar-quartz-tourmaline portion of the dike is said to have given 1.15 per cent of tin. Tin ore is also reported to have been found in float on the same dike at its outcrop near Lost River.

At a number of places in the neighborhood of Cassiterite Creek the proximity of dikes is indicated by the vast number of siliceous veinlets in the limestone. Every minute crack has been filled by silica, and in weathering the outer portion of the limestone is dissolved, leaving a skeleton of the silica with hard, jagged edges. Many of these veins are not over one two-hundredth of an inch in thickness and in those that are thicker epidote, vesuvianite, garnets, fluorspar, lithia micas, cassiterite, and probably other minerals often make their appearance. Close to the Cassiterite lode there are many small veins from one-eighth to 1 inch thick of zinnwaldite, one of the lithia micas, crystallized at right angles to the walls, carrying also a little fluorite, cassiterite, and wolframite. There are other quarter-inch veins of a mineral which on analysis by W. T. Schaller, of the United States Geological Survey chemical laboratory, was found to have the composition of margarite, but which does not show the fine cleavage of margarite, and seems to be isotropic. Float calcite, containing cassiterite, has been picked up a number of times. The mineralization has been very great, but has taken place in a comparatively restricted area, especially that part which shows cassiterite, and in this fact lies the greatest ground for doubting the future development of large tin deposits in this district. Three known tin-bearing veins of noticeable and possibly workable size occur in the limestone. These will be described in some detail.

There is a quartz vein about 4 inches wide dipping 30° S. an eighth of a mile above the Cassiterite lode, on what is known as the Jupiter claim, but it has been traced only a short distance. The vein has not filled the crevice in which it was deposited, so that combs are formed by the intergrowth of quartz and cassiterite crystals, the latter reaching an inch in diameter. Many of the crystals have been sheared by a slight movement that has taken place along the vein. The limestone is much metamorphosed for about 4 feet on each side of the vein, and is somewhat impregnated with cassiterite, though to what extent is not known. During 1904 a few tons of ore were extracted from this vein and shipped to Seattle.

Another vein occurring a few rods northeast of the one just described is about 4 inches thick, strikes N. 20° E., with a vertical dip, and has been traced between 200 and 300 feet. It is composed of slender quartz crystals forming interlocking combs. On the quartz crystals and sometimes embedded in them are small crystals of cassiterite, occurring singly and in small masses, showing that more of the cassiterite was deposited in the later than in the earlier stages of the vein's formation. Some of the crystals are beautifully iridescent. There are traces of copper and wolframite, and a small amount of lithia mica occurs in the vein (specimens T5AH67, T5AH68).

On the hill between Lost River and Cassiterite Creek is a third vein about a quarter of a mile southwest of those already described. It is from 1 inch to 6 inches thick, dipping 30° S. 10° W., and has been followed by an open cut about 30 feet along the strike and 10 feet along the dip. The quartz and cassiterite are rather finely crystallized and fill the vein with a banded structure. There is also a small amount of iron pyrite, arsenopyrite, and lithia mica, with occasional copper stains in the vein.

The limestone is much altered for several feet on each side of the veins, and whether they will pay to work seems to depend largely on how much tin is carried in the altered limestone accompanying them. Should the dike deposits be mined, at least the first-described vein would probably pay if worked in connection with them. There seems little doubt that these veins can be traced to the rhyolitic dikes in the neighborhood.

No tin-bearing veins have yet been found in Tin Creek valley, although some float pieces of tin ore are said to have been found. Pyritiferous granite collected by Collier and the writer was shown to carry a small amount (0.3 per cent) of tin,[a] but whether it occurs as an oxide or sulphide (stannite) is not known, as the determination used[b] would not show in what form the tin occurred.

A small amount of galena, by no means in paying quantity, and some pieces of "mountain leather," a matted form of tremolite asbestos, were found with decomposing calcite veins near the granite boss on Tin Creek. Float from another vein about 2 inches wide was determined by Schaller as diaspore, a hydrate of alumina.

Prospecting is being done for galena about 5 miles from the mouth of Lost River, but as the shaft was said to be full of water at the time it was not visited.

### CAPE MOUNTAIN AREA.

On Cape Mountain prospecting for tin has been carried on since 1902, and a large amount of work has been done, especially by the Bartells Tin Mining Company. It is a particularly bleak, inhospitable portion of the country, and the determination and endurance of Alaskan prospectors is exemplified in the men who are attempting to open up the tin mines in this district, and this applies with equal force to Buck Creek and only in a less degree to Lost River. Fine pieces of float tin ore made up of quartz, tourmaline, and cassiterite were found at many places in the vicinity of Cape Mountain, but it was not until 1904 that the ore was found in place. During 1905 there were further discoveries of tin ore that made the outlook more encouraging.

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[a] Collier, A. J., The tin deposits of the York region, Alaska: Bull. U. S. Geol. Survey No. 229, 1904, p. 22.

[b] Idem, p. 43.

### GEOLOGY.

As has been stated, Cape Mountain is a large mass or boss of granite, thrust up through Carboniferous limestone. It is 2,300 feet high, about 5 miles across in an east-west direction, and something less north and south. The upper 400 to 450 feet of the mountain is a dark quartz-sericite-schist, separated from the granite by 10 or 12 feet of thin-bedded limestone in alternating dark and white bands an inch or two thick. The white strata are due to the limestone having been changed to wollastonite (a lime silicate), probably by siliceous solutions accompanying the intrusion of the granite. In the darker strata the color is probably due to the segregation of carbon from the more metamorphosed portions, as it is much darker than the unaltered limestone.

From the main mass of the granite, dikes and sills varying greatly in size cut the limestone in all directions. The limestone is often altered to wollastonite for a distance of several feet in each direction from sills and dikes but a few inches thick. There is such an occurrence on the shore about a mile west of Tin City, where a sill of alaskite (quartz and feldspar) about 18 inches thick has altered the limestone in this way both above and below through a distance of about 3 feet. Radiating crystals one-eighth inch in thickness and 4 inches long run directly across the bedding, and the washing of the waves has made them stand out in distinct relief. At other places the wollastonite forms delicate radial bunches of crystals lying in the bedding planes of the limestone. There are often thin layers of marble in the wollastonite of a faint blue color. At one place on the northeast side of the mountain the limestone above a granite dike has been replaced by silica over an area that was crossed in one direction for perhaps 200 feet, though its other dimensions are unknown. This occurrence will be referred to again. There is occasionally a little fluorspar in some of the dikes, but it is comparatively rare in this district. There are also occasional small segregations of glistening white muscovite mica, which has been taken for lithia mica, but no lithia could be detected by Schaller in specimens collected by the writer (specimen T5AH20).

Basaltic dikes, from 3 or 4 feet to 30 feet in width and composed almost wholly of olivine, plagioclase, and magnetite (specimens and slides T5AH4 and T5AH19), cut both granite and limestone. They are occasionally amygdaloidal with the amygdules filled by zeolites. The rock is fresh, black, and hard, and is accompanied by little contact phenomena. The basalt seems to be later than the tin deposits, and so it is not likely that any tin will be found in connection with it except as it may happen to cut across tin veins or tin-bearing rocks.

### JOINTING AND FAULTING.

The granite is very much jointed, the two most prominent series of vertical joints running N. 60° E. and N. 50° W., while many lesser joints run in directions between these. A system of almost horizontal parallel joints gives the granite a platy structure in places. Other joint planes are inclined at various angles. The two main series of joints cause the granite to weather into numerous columns left standing upon the shoulders of the mountain, giving them an appearance of being capped by rows of ruined factory chimneys. These columns vary considerably in height and thickness, reaching a height of 30 feet with a base of about 4 by 8 feet, while others are much shorter and thicker. Between the columns the jointing seems to have been so close that the granite weathered readily and crumbled out, leaving the less jointed, more solid portion standing. The general level of the shoulders is remarkably even and furnishes an interesting example of how evenly ridges may erode under ordinary subaerial agencies. The height to which the columns reach shows probably only a part of the rock removed.

Faulting is very frequent, and although the amount or direction of throw can not be determined the accompanying crushing is sometimes considerable. One mile west of Tin City, at the contact of the limestone and granite, there is a crushed zone 4 feet in width along which a tunnel has been driven about 80 feet to prospect a sill of alaskite that carried some pyrite and tourmaline. Assays are said to have given values of from $3 to $180 per ton in gold, but these values did not last as the tunnel advanced. In other places in the area faulting and crushing have produced almost as great an effect, and these factors introduce a serious element of doubt in tin mining, for, as will be shown later, the tin veins are affected by the faults.

### TIN DEPOSITS.

Float cassiterite has been found quite extensively near Cape Mountain. It is reported from the vicinity of Cape Prince of Wales, and a fine piece weighing several pounds is said to have come from a point about 12 miles east of the cape. Little has been seen on the south side of Cape Mountain, and by far the largest amount has been found on the north and northeast sides, where masses of nearly pure cassiterite weighing from 20 to 30 pounds have been picked up. The float indicates three distinct sets of veins—veins of cassiterite with tourmaline and quartz, tin-bearing quartz veins, and veins of almost pure cassiterite. The latter apparently cut the limestone, but had not yet been found in place at the time of the writer's visit. Fragments of the first mentioned are much the most plentiful and are distributed over the largest area; the other two, so far as known, have each been found in but one locality.

One noteworthy feature is the distinctive character of the ore from different parts of the area. As soon as a little familiarity with the different claims is acquired it is easy to tell the particular locality from which specimens have come by their color, crystallization, etc.

The plant of the Bartells Tin Mining Company includes an assay office, storerooms, engine and living rooms under one roof at Tin City. A gasoline engine furnishes power for electric drills used in mining, to which the current is carried about a mile across the mountain by bare copper wires. The electric drill seems peculiarly well adapted for work in this region. It is mobile, although a track is required for moving the motor accompanying each drill, and in such prospecting work as has been carried on here it has been a great advantage to have a central plant at headquarters near the shore. Another advantage is that the cold of the tunnels does not affect it, while air pipes would probably soon become clogged with ice, and steam could not be considered. A 3-stamp Merralls mill with Wilfley tables was being erected at the time of the writer's visit, and a well to obtain water for winter working was being sunk near by. The finding of water in this frozen ground is problematical, though not totally hopeless, there being strange differences in the depth of the frost at different places. At Eagle water is obtained below 50 to 60 feet of frozen ground; at Rampart a hole 225 feet deep had not reached the depth of the frost; at Nome in places there is no permanent frost in the ground, while at other places it goes down over 100 feet; but the country around Cape Prince of Wales is colder than at Nome, with a noticeably shorter summer season, so that it seems probable that the frost will be deeper.

Prospect tunnels and shafts have been dug at numerous places and a large amount of work has been done upon them. At the time of Collier's visit in 1904 some small tin-bearing veins had been struck in a prospect tunnel known as the "Lucky Queen,"[a] about 1½ miles north of Tin City. This tunnel was unused and largely filled with ice in 1905, and the principal operations of the company had been transferred to the North Star claim, lying a short distance east and at a somewhat lower altitude. These two tunnels are located well toward the east end of a granite mass that seems to be a large dike, though time did not admit of tracing out its relations, and it may be a portion of the main mass of granite over which enough limestone still lies to cover its larger proportions. Another prospect tunnel that is said to cut through a small thickness of limestone before striking the granite has been started 150 or 200 feet below the North Star tunnel.

By far the largest and most promising prospects so far found are in the North Star, which was driven into the granite a little over 200 feet in a general direction of about S. 70° W. Older parts of the workings are hard to examine owing to their being covered with a beautiful coating of frost from one-half to 1 inch in thickness. The frost is said to form noticeably only during the summer, when the air from the outside brings in moisture which forms in bristling feathery crystals over every object in the mine. Near the entrance the surface water dripping from the roof forms icy stalactites and stalagmites that later grow together, making gradually thickening pillars, which, unless removed, choke the tunnel.

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[a] Collier, A. J., Recent development of Alaskan tin deposits: Bull. U. S. Geol. Survey No. 259, 1905, *pp. 124-125.*

A short distance from the mouth of the tunnel a large limestone inclusion was passed, through which formed the upper 4 feet of the tunnel for a distance of about 28 feet. Faulting was evident along the edges of the limestone. About 100 feet from the mouth of the tunnel another inclusion of limestone was struck that was in a broad band 10 to 20 feet thick, striking about northwest and dipping variably northeast. Along both sides of this limestone was a considerable amount of iron oxide, carrying some tin. The contact of the limestone and granite was followed to the northeast about 52 feet, where the dip became almost vertical. A winze was sunk 20 feet, when the dip became gentler (17°), but 70 feet from the winze the contact dips 37°.

From the foot of the winze an incline with its floor on the limestone has been run about 90 feet, parallel to but in the opposite direction from the main tunnel. Tin-bearing veins

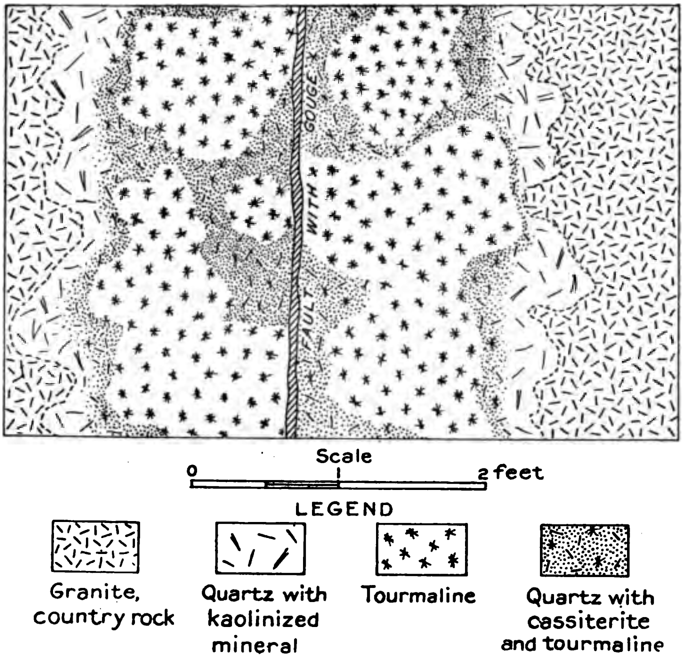
FAULT WITH GOUGE
Scale
0
1
2 feet
LEGEND
Granite, country rock
Quartz with kaolinized mineral
Tourmaline
Quartz with cassiterite and tourmaline

FIG. 10.—Diagrammatic section of cassiterite-bearing replacement vein in North Star mine.

were struck at several places along the course of the incline and drifts turned off at two places. One of these 60 feet from the winze is 18 feet long, turning to the north and then to the east, and is said to carry pay ore, but had not been systematically sampled. The second drift, 70 feet from the winze, turned southward under the main tunnel. At the point of turning 3 feet of rock much impregnated with iron oxide and carrying a large amount of cassiterite were encountered. When thawed, the rock fell to pieces, being finely crushed through the whole width. This particular place seems to be the junction of a number of faults which carry but little gouge and whose character and extent are unknown. Near the faults the granite is sometimes much changed, having lost most of its feldspar, which is replaced by quartz, black tourmaline in very fine crystals, and varying amounts of cassiterite. It seems likely, also, that the quartz has been largely replaced by secondary quartz, as it shows none of the "smoky" appearance so common in the area, and that most of such feldspar as is present may have been dissolved and redeposited (specimen T5AH32). As silicification proceeds, the tourmaline also increases in amount, forming irregular masses. The tourmaline is occasionally replaced by pyrite (specimen T5AH28). A gneissoid rock, a couple of inches thick, occurring along some of these fault lines is probably a crushed portion of the granite (specimen and slide T5AH40). Tin-bearing granite was struck at a number of places in this drift, but the distribution seemed irregular. About 20 feet from the mouth another and by far the most promising ore body was found. This ore body follows a vertical fault with from one-fourth inch to 1½ inches of gouge, striking, as nearly as could be determined, N. 56° W., and was formed by the replacement of the granite, through a space of from 12 to 18 inches on each side of the fault, by quartz, tourmaline, cassiterite, feldspar, and a now decomposed mineral in long, white crystals (fig. 10). The whole vein averages between 2 and 3 feet in width and appears almost diagrammatic against the surrounding granite. Replacement of the granite seems to be complete and the mineralizing solutions evidently came up along the fault. The various minerals show an apparent tendency to segregate, and this applies particularly to the tourmaline and quartz, while the cassiterite is more apt to be associated with the quartz than the tourmaline, although there are generally needles of tourmaline running through the cassiterite. The tourmaline in irregular bunches of slender black crystals, from 6 to 12 inches in diameter, occurs either next to the fault or surrounded by other minerals. The cassiterite associated with the quartz forms irregular masses and bands through the body. As elsewhere around Cape Mountain, the granite is greatly jointed and both tin ore and tourmaline extend to a joint and apparently stop abruptly, the rock beyond the joint showing very different characteristics.

Little that is definite can be said of the richness of the deposit, as it was struck only the day before the writer left the vicinity and it had not been sampled, but it appears promising. It is reported that work during the next few days showed the ore body to be increasing in richness. From the appearance of the vein, its width and amount of mineralization, and the known depth of tin veins in other parts of the world, it seems reasonable to expect that it will extend downward, unless faulted off, a fear from which one can not escape in such broken rocks. Some tin ore was found in the main tunnel 30 feet above, which may have been the same deposit, though at that point the vein is said to be small.

About 1 mile north by west from the North Star and 2 miles northeast of Cape Mountain a large amount of excellent float-tin ore has been picked up in the vicinity of a granite sill in the limestone on the Walker, Lovell & Co. prospects. The cassiterite is fine grained and of a peculiar shade of purplish gray with a tinge of brown, and is embedded in masses of fine needles of light-blue tourmaline, occasionally with portions of granite adhering to the mass. Lumps of the ore have been found that were estimated to weigh 400 pounds or over, of which by far the larger part was tourmaline. A cabin has been built and a prospect tunnel run into the limestone nearly 100 feet at this point, and about a quarter of a mile north by west an open cut made which uncovers two thin sills, one of aplite carrying small crystals of fluorspar (specimen T5AH24) and one of coarse pegmatite. The sills are accompanied by about 3 feet of a fine-grained greenstone, which is probably altered limestone. It is said that assays of this greenstone made in Nome gave about 1 per cent of tin, but tests by E. C. Sullivan, of the United States Geological Survey, failed to show a trace of tin.

About half a mile east of Walker, Lovell & Co.'s cabin Goodwin & Carlson had run a prospect cut along the contact of a granite dike with the limestone country rock. Faulting is evident, there being 2 or 3 feet of crushed rock along the contact. The granite carries some fluorspar and brassy-looking pyrite. The limestone above the granite is silicified through an area several hundred feet wide, silicification gradually lessening in the outer part of the area.

Some good float of dark, translucent cassiterite in a groundmass of light-blue tourmaline (specimen T5AH6a), in pieces ranging in size to over a foot in the longer dimension, was picked up, but none had been found in place at the time of the writer's visit. Later its discovery was reported and about half a ton of ore similar to that described was brought to Nome.

The United States Alaska Tin Mining Company has a cabin and a couple of small warehouses on the beach at Tin City and has started a 10-stamp mill a quarter of a mile back from the beach. Power is to be furnished by a gasoline engine. The claim on which the company is at present working is situated on the north side of Cape Mountain, at an altitude (barometric) of about 1,750 feet. A shaft sunk on this claim is said to be 15 feet deep, but was filled with water so that it could not be seen at the time it was visited.

Along the side of the hill on each side of the shaft are a large number of quartz blocks, some of which contain cassiterite in almost colorless, gray, brown, and black lustrous crystals (specimens T5AH18, T5AH18a). No other minerals are seen in the quartz. The granite country rock in the shaft is somewhat altered and is said to carry tin. A specimen said to be from this place shows cassiterite crystals (specimen T5AH41).

A contract was let in the fall for 300 feet of tunnel to be run during the winter from a point lower down the hill in the hope of cutting within that distance the vein from which the quartz float is derived.

Prospecting has been or was being done at a large number of other places. It was said that float tin ore had been found nearer the cape and some prospecting done, but the locality was not visited. At another point a dark basic dike was being prospected by a crosscut, but in such rocks the chances of finding tin ore are small.

### BUCK CREEK AREA.

So far no producing tin lodes have been found in the Buck Creek area, but it is of interest that several small tin-bearing veins have been found during the past season.

The country rock is slate, and heretofore outcrops of igneous rocks had not been seen, although it was felt that there must be such occurrences; but a number of granite dikes are now known at various points in the hills running northward from Potato Mountain. A number of narrow veins of quartz 2 or 3 inches wide carrying small clusters of cassiterite crystals accompanied in each case by iron pyrite, generally more or less arsenical, have been found cutting the slates on these hills. The pyrite weathers away, leaving the cassiterite in spongy spaces in the quartz (specimens T5AH53, T5AH55, T5AH56, T5AH58). No minerals besides the pyrite and quartz have been seen in the veins, and with the possible exception of a small amount of wolframite, none have been found in the Buck Creek gravels other than hematite and magnetite, which are derived from pyrite.

On a hill west of North Fork of Buck Creek a granite dike said to be 15 feet wide is being prospected for tin. A specimen given the writer (specimen T5AH62) shows a short narrow opening carrying black cassiterite and small crystals of quartz.

The hope of paying deposits in the slates would seem to lie in finding stockworks (networks of small veins) rich enough to pay for working. These have been successfully worked in slate in Cornwall and the Malay Peninsula.

At many places veins and small replacement deposits of pyrite are found in the slates, and these have been said to carry stannite (tin pyrites). Six samples collected at points where stannite was said to exist were submitted to E. C. Sullivan, of the United States Geological Survey chemical laboratory, but he was unable to find a trace of tin in them.

### EARS MOUNTAIN.

Prospecting on Ears Mountain continued during the summer of 1905, probably a dozen men being there during different parts of the season. While cassiterite undoubtedly has been found on the mountain, it is nevertheless true that most of that brought out as such is something else. The mineral generally mistaken for cassiterite is tourmaline, and at Ears Mountain the two are remarkably similar, for often neither shows its crystal habit well and both are black and without cleavage, so that men who have seen the cassiterite-bearing rocks are ready to declare that tourmaline-bearing rocks of similar appearance are "exactly the same" as those which showed tin on assay. After having become somewhat familiar with these rocks, the writer must confess his inability to differentiate them by eye alone.

Another mineral that has been repeatedly mistaken for cassiterite is augite, which occurs as peculiarly large black crystals, reaching 2 inches or over in length in granitic rocks of rather dark color (specimen T5AH109). The augite is not so difficult to tell from cassiterite as tourmaline, having a much lower specific gravity and breaking along distinct parallel lines, which cassiterite will not do.

### COST OF MINING.

At present wages in the York region are $5 and board, and good board can not be considered as worth less than $1.50 to $2.50 per day, making wages the equivalent of $6.50 to $7.50 per day. At Cripple Creek, Colo., where average wages may be considered as perhaps $3.75, in the Portland mine,[a] the cost of removing all rock, both barren and ore bearing, was $3.13 per ton. The rock here is only partly granite, a part being softer breccia and intrusive. At Butte, Mont., the cost of mining in granite has been about $3.50 per ton,[b] with wages averaging about $3.50 per day. An average of these two examples gives about $3.32 per ton for the cost of raising ore, exclusive of milling and smelting charges. In view of the cost of wages, materials, machinery, etc., it is hardly possible to suppose that the cost of mining in the York region can be less than twice this amount, or about $6.64 per ton. In 1903 the price for which black tin (i. e., the cassiterite concentrated from the ore) sold from the Cornwall mines was 16.1 cents per pound, but no data are at hand as to its purity. On the assumption that it was about 70 per cent pure, this would be about 23 cents per pound for the contained tin. At $6.64 per ton for ore raised and 50 cents for milling and concentrating, a total of $7.14, it would take a minimum average of about 31 pounds of tin per ton of rock mined, or 1.55 per cent, to pay for working. However, this estimate allows nothing for transportation, sinking fund, prospecting, legitimate profit, etc., and it seems safe to figure that under present conditions nothing less than 2½ per cent ore can be worked with a reasonable assurance of profit.

## PLACER DEPOSITS.

### BUCK CREEK.

The placer tin deposits on Buck Creek are the only ones in Alaska from which there has been any production and have yielded to date about 91 tons of ore that would average probably 65 per cent of metallic tin. In this amount is included the production of 1905, which was very small, owing to bad weather and other reasons. During the year the trail between York and Buck Creek was changed somewhat. Instead of following Anikovik River to a point opposite the head of Grouse Creek the trail now leaves the river at Ishut Creek, which is followed to its head, then crosses a narrow divide and traverses Gold Creek to Grouse Creek and that to the mouth of Buck Creek. By this change the bad divide between Grouse Creek and Anikovik River is avoided. The total haul is from 14 to 16 miles.

But one company operated on the creek during the season. Its plant consisted of an oil-burning 35-horsepower upright boiler and engine, French scraper with belt conveyor, and sluice boxes elevated 16 feet above the ground. Two sets of sluice boxes side by side are used, so that there need be no stoppage of work for clean-ups.

The work has shown the gravel to carry an average of from 20 to 30 pounds of concentrates, running from 60 to 70 per cent of metallic tin and about 40 cents in gold per cubic yard. The gravel is from 120 to 160 feet wide, averaging about 125 feet, by 3 to 6 feet in depth, averaging about 4½ feet. The tin-bearing gravels extend from the mouth to Peluk Creek, a tributary of Right Fork. Left Fork and Peluk Creek are said to also carry stream tin, but in the case of the latter obtaining water for sluicing will be a serious difficulty. Sutter Creek has so far shown but little stream tin. There is probably a length of about

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[a] Finley, J. R., Ninth Ann. Rept. Portland Gold Mining Company, February 2, 1903, p. 13.
[b] Communicated by W. H. Weed.

4 miles of tin-bearing gravels in the Buck Creek Valley. It has been reported that scheelite and monazite were found in these gravels in paying quantities, but the writer has been unable to find either. The specific gravity of scheelite (5.9–6.08) would make it practically impossible to wash it from the stream tin, whose specific gravity is 6.4 to 7.1 and is liable to be lower on account of impurities, so that were scheelite present it would be readily noticed from its light color. The monazite is somewhat lighter in weight, its specific gravity being about 5 (4.9–5.26).

The great interest that these deposits have aroused is shown by the amount of "experting" that has been done. At least seven parties have been sent to Buck Creek by firms or private persons to examine and report on the tin gravels, and the expense has been probably much in excess of $50,000. Holes have been started where bed rock could not be reached except with a steam pump or a bed-rock drain, neither of which were had, and signs of crosscuts are almost wholly wanting, yet reports were probably made on the depth and value of these gravels. One published report states that it was "impossible to examine any of the rock in place except on the extreme summits," and yet the bare slate stands along the creek in a bluff 75 feet high.

### GROUSE CREEK.

Grouse Creek, into which Buck Creek flows, has so far shown little stream tin above the confluence, but below prospectors report from 3 to 40 pounds of stream tin per cubic yard of gravel through a breadth of 100 feet. Bed rock was not reached and the depth of gravel is unknown. It was said that the best prospects are on the western side of the valley and that the tin varies in size from small crystals to lumps as large as one's fist.

### RED FOX AND OTHER CREEKS.

The creeks flowing into Lopp Lagoon from the hills north of Buck Creek are all said to show good prospects of stream tin, but the extent of the tin-bearing gravels is as yet unknown and the question of water for sluicing will be a serious one.

### MINT RIVER.

Mint River, into which Grouse Creek flows, has been widely advertised as having tin-bearing gravels, but prospectors who worked on the stream during the last summer reported that they were unable to find any stream tin. Prospectors of former years, however, have reported its occurrence.

### EARS MOUNTAIN.

Stream tin has been reported in several of the streams flowing from the northeast and east sides of Ears Mountain, but they have not been prospected enough to show their extent.

## OTHER SEWARD PENINSULA DEPOSITS.

Dick Creek, Old Glory, and a few other creeks of the Arctic slope east of Ears Mountain carry some stream tin, but have shown none of commercial importance. Goldbottom Creek, at the head of Snake River, about 18 miles north of Nome, carries a little stream tin, whose occurrence is interesting geologically because no granite is known in the immediate neighborhood. However, on the east side of Mount Distin there are a number of acidic intrusives that have been crushed into gneisses, and some such occurrence may be buried beneath the tundra and glacial débris at the head of Goldbottom Creek. Some of the cassiterite pebbles appear flattened, as if they may have come from such a source. Fred Gulch, on the north side of Mount Distin, is reported to carry a small amount of stream tin similar to that in Goldbottom Creek.

To show how frequently prospectors are deceived it may be well to note that tin was rather widely advertised as being found at the head of Nabesna River, but in samples tested the mineral thought to be cassiterite proved to be garnet.

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